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**ENGINEERING STUDY
FOR THE CONVEYOR AND AREA FILL SYSTEMS
FOR THE ENVIRONMENTAL RESTORATION
DISPOSAL FACILITY**

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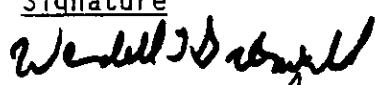
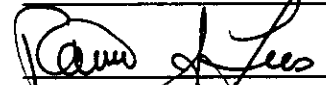




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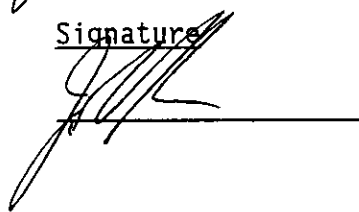
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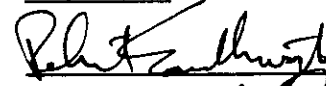
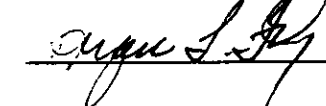
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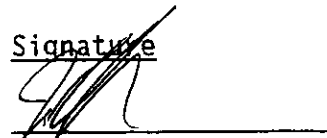
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ACRONYMS

3H1V	3 horizontal to 1 vertical grade
AC	alternating current
ARARs	Applicable or Relevant and Appropriate Requirements
CAMU	Corrective Action Management Unit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CH	contact-handled
D&D	Demolition and Decommissioning
DC	direct current
DOE	U.S. Department of Energy
Ecology	Washington State Department of Ecology
EOD	Explosive Ordinance Disposal
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
ERSDF	Environmental Restoration Storage and Disposal Facility
FDC	Functional Design Criteria
ft ³	cubic feet
HCR	horizontal control rod
Hz	hertz
IDO	indefinite delivery order
INEL	Idaho National Engineering Laboratory
lbs/ft ²	pounds per square foot
lbs/ft ³	pounds per cubic foot
LDRs	Land Disposal Restrictions
LLW	low-level radioactive waste
MHz	megahertz
mm	millimeters
mph	miles per hour
mrem	millirem
mrem/hr	millirems per hour
mrem/yr	millirems per year
MTRs	Minimum Technology Requirements
NCP	National Contingency Plan
NEMA	National Electrical Manufacturer's Association
O&M	Operations and Maintenance
ORNL	Oak Ridge National Laboratory
PA	Performance Assessment
RCRA	Resource Conservation and Recovery Act
RH	remote-handled
SAR	Safety Analysis Report
TORCE	Teleoperated Remote Controlled Excavator
TRU	transuranic
TSCA	Toxic Substance Control Act
UMTRA	Uranium Mine Tailings Reclamation Act
USACE	U.S. Army Corps of Engineers
V	volts
VSR	vertical safety rod
WAC	Washington Administrative Code
WHC	Westinghouse Hanford Company
yd ³	cubic yards
yd ³ /hr	cubic yards per hour

1.0 INTRODUCTION

This study is one of a number of engineering studies being conducted to develop the design concept for the Environmental Restoration Disposal Facility (ERDF) at Hanford. The objective of this engineering study is to compare the use of a conveyor system to the use of trucks to transport waste from the receiving facility to a large area fill for disposal. A second objective is to evaluate the area fill trench configuration.

1.1 ERDF DESCRIPTION

The U.S. Department of Energy (DOE) has tasked the U.S. Army Corps of Engineers (USACE), Walla Walla District with the development of the conceptual design for the ERDF at the Hanford site near Richland, Washington. The production of plutonium and related activities since 1943 has resulted in significant environmental (primarily soil) contamination on the Hanford site. The ERDF will serve as the disposal facility for the majority of wastes excavated during remediation of waste management sites in the 100 Area, 200 Area, and 300 Area of the Hanford facility. The initial phase of the overall project has been designated by Westinghouse Hanford Company (WHC) as Project W-296, which is defined as the design and construction of facilities for the disposal of waste generated through the year 2001. The operation of the facility will be performed under another project. Only waste from the 100 Area and 300 Area will be disposed at the ERDF during Project W-296. The USACE has tasked Montgomery Watson to conduct the engineering study under Delivery Order No. 0022, under the indefinite delivery order (IDO) contract number DACW68-92-D-0001 with the Walla Walla District. USACE, Golder Associates, Inc., and Harris Group, Inc. assisted Montgomery Watson in the preparation of this report.

The current concept for the ERDF calls for burial of remediation derived waste in trenches up to 33 feet deep with eventual cover by the Hanford Barrier (assumed for purposes of this study to be 15 feet in thickness). The Hanford Barrier will be specifically designed for this site to prevent infiltration and limit access to the waste for as long as reasonably possible. Some or all of the waste disposal units may be lined, and some of the waste may be buried in containers, depending on the nature of the waste and the outcome of future regulatory determinations. Along with the disposal units, the ERDF will include ancillary waste handling and transportation facilities such as an administration building and facilities to decontaminate equipment and containers.

It is anticipated that the ERDF will be located near the 200 Areas in the center of the Hanford site. This location was selected due to the central location and the favorable geologic conditions associated with this portion of the Hanford site. The site location is currently being evaluated by DOE.

1.2 PURPOSE AND SCOPE

As described in the statement of work for this project, "The purpose of this work.... is to perform.... design development for the area fill concept of waste material disposal for the W-296 project." This study also provides a systems comparison; however, the systems comparison is divided into two separate systems with the transportation systems compared in Section 5 and the area fill concept compared in Section 6. This study evaluates alternatives for transporting the low-level radioactive waste (LLW) and other wastes within the ERDF (see Section 5). This

study also evaluates trench configurations (see Section 6) and the disposal of both contact-handled (CH) LLW and containers containing remote-handled (RH) LLW (see Section 2). The following work elements were identified in the Scope of Work by DOE and are addressed in this engineering study:

- Feasibility of disposing of containerized waste and backfilling with bulk waste.
- Type and number of trenches required (i.e., lined/unlined). An evaluation of associated regulations will be performed which may require segregation of wastes for disposal, evaluate waste compatibility, and contact private firms and DOE facilities which may have similar experience.
- Time and motion studies related to the area fill and conveyer concept.
- Develop the sizing of the mechanical conveying system.
- Develop the waste acceptance criteria as applied to bulk waste-handling systems.
- Identify the specific systems designed to separate and process solid materials for bulk handling (e.g., shredding, crushing, compacting).
- Develop detailed process flow chart/diagram of the bulk materials handling system and the area fill trench.

Because of the importance of the area fill concept to the project, the USACE directed that the purpose and scope of this study be broadened to address the following issues:

- The design of the trenches may be influenced by the type of waste disposed in the trenches because of regulations which may either require separate disposal areas for different types of wastes or lined trenches. These issues are discussed in Section 2.1.
- Some wastes may be disposed using single-use/disposable containers. These containers may eventually degrade and fail, which could allow waste settling and damage to the Hanford Barrier. This issue is discussed in Section 2.2.
- In addition to the container causing settling, the overall waste material may settle over time which could damage the Hanford Barrier. This is discussed in Section 2.3.
- Truck transport of waste within the ERDF was assumed for previous studies. This study evaluates the use of mechanical conveyors as an alternative means of transportation. The conveyor system has certain limitations on material that can be conveyed. These limitations are presented in Section 3.1.
- Alternative types of rail cars for transportation might be better suited for the conveyor option and these are discussed in Section 3.2. The use of liners and sacks to minimize contamination of the rail cars is also discussed in this section.
- The mechanical conveyor system is described in Section 3.3 and is compared to truck transportation in Section 5.0.
- Decontamination of the conveyors and the rail cars is presented in Section 4.1.
- The benefits of using the material excavated during the construction of the ERDF trenches is presented in Section 4.2.

- The maintenance of equipment is discussed in Section 4.3.
- Various trench configurations are presented and compared in Section 6.0. Previous studies have assumed a large number (25 to 30) of narrow trenches. In this study, this is referred to as the base case trench configuration. This study evaluates a much smaller number (one or two) of wider trenches. In this study, the wider trenches are referred to as the area fill trench configuration. In addition to these wide trenches, there may be additional small trenches for other wastes such as hazardous/dangerous and hazardous/mixed wastes.

1.3 EXECUTIVE SUMMARY

The principal purposes of this study were to determine the cost effectiveness of a conveyor transportation system and to compare the cost effectiveness of conventional disposal trenches with the area fill trenches. Additionally, various issues associated with trench design, conveying of waste within the ERDF, and trench configurations were considered. This Executive Summary provides a brief summary to orientate the reader to where in this report the issues are discussed and to list the final results of the report so that the reader does not become confused with interim conclusions.

This study evaluated the trench design in Section 2.1 based on the regulations for the expected types of waste to be disposed. This study also evaluated containerized waste disposal in Section 2.2. Future safety analyses will determine the operational controls for the facility and the need for controlling worker exposure by containerizing radioactive wastes above a certain level of activity. In the event that containerization is required, this study determined that the containers should be placed in a single layer with at least two feet between containers and that the material inside the containers must have a high enough density to support the overburden once the containers corrode. The placement of the waste material is discussed in Section 2.3.1 and the use of vibrating rollers during waste placement is the preferred alternative of compaction. Future waste material characterization studies and safety analyses will determine the operational controls for this facility and the need to utilize remote controlled equipment. In the event that worker exposure makes remote operations necessary for certain wastes, then Section 2.3.2 evaluates safety through use of remotely controlled equipment and recommends a remote control system that allows either remote or direct control so that as conditions warrant, remote operation can be readily implemented.

This study provides a system comparison of truck transportation and conveyor transportation of the waste material from the ERDF railhead to the disposal trench. Truck transportation is recommended for a number of reasons as described in Section 5. Section 3.1 evaluates the type of equipment needed to process the waste for conveyor transportation and Section 3.3 describes a workable conveyor system but this is no longer pertinent as truck transportation is the preferred alternative. Section 3.2 evaluates other types of containers, rail cars, or liners for transportation of the waste from the remediation sites to the ERDF and determined that the use of removable containers is the preferred method. The main reason that alternative rail car configurations is not acceptable is the extensive decontamination needs of these rail cars which is described in Section 4.1. The potential to use the material excavated during construction of the trench in the liner, as daily cover, and as part of the final cover are described in Section 4.2. Even after these uses, there will be excess material remaining which could be back-hauled to the remediation sites for recontouring. All remaining excess material will need to be graded to promote drainage at the ERDF.

Section 6 compares a number of trench configurations and determined that the area fill configuration A would use less than 50 percent of the land area needed for the base case trench

configuration and could save over \$700 million in construction costs. The 70-foot deep area fill configuration C would use less than 26 percent of the land area needed for the base case trench configuration and could save over \$1,000 million in construction costs.

Section 7 provides an overall list of the summary and conclusions of the various sections of the report.

2.0 TRENCH DESIGN

The design of the trenches may be influenced by the type of waste disposed in the trenches because of regulations which may either require separate disposal areas for different types of wastes or lined trenches. These issues are discussed in Section 2.1. Some wastes may be disposed using single-use/disposable containers. These containers may eventually corrode which could allow waste settling and damage to the Hanford Barrier. This issue is discussed in Section 2.2. In addition to concerns with settlement associated with single-use/disposable containers, the overall waste material may settle over time which could damage the Hanford Barrier. This is discussed in Section 2.3.1. The remainder of Section 2.3 discusses other operation issues associated with the trench operation.

2.1 TYPES AND NUMBERS OF TRENCHES

For purposes of this evaluation, the **type** of trench refers to whether the trench will be lined or unlined, which in turn depends on the regulations for each type of waste. The **number** of trenches which will be required for disposal of the various types of waste that the ERDF must accept will depend on the regulations requiring segregation of wastes by radiation level and/or chemical waste constituent. Therefore, the **number** of trenches depends primarily on the characteristics of the waste. The remainder of this section will evaluate the regulatory requirements (where established) for various waste types and will determine the number of separate waste disposal trenches that will need to be constructed to accommodate these wastes.

It may be desirable to have two or more parallel trenches for constructability, to accommodate transportation systems such as conveyors, or to fit within particular site boundaries. Such operational constraints on the number of trenches cannot be determined at this time because the associated factors have not been finalized. These considerations will be addressed during the conceptual design process.

2.1.1 Lined vs. Unlined Trenches

Landfills for disposal of hazardous chemical wastes must be double lined and include leachate collection and detection systems. These requirements are established as part of the Resource Conservation and Recovery Act (RCRA) and are specified in detail in 40 CFR 264.301 and implementing technical guidance. On the state level, the RCRA requirements are embodied in the *Dangerous Waste Regulations* Washington Administrative Code (WAC) 173-303-665. Some of the wastes generated by remedial activities at the Hanford Site are expected to include RCRA hazardous constituents (primarily heavy metals and inorganic salts), although such wastes are expected to be only a small fraction of the total waste volume. These wastes will need to be disposed of in a lined facility that satisfies State and Federal requirements. Consideration was made of the functional equivalency of the unlined trench with the Hanford Barrier to the RCRA design. However, because the equivalency would need to be demonstrated on a component by component basis, equivalency of the unlined trench is not possible (although under Corrective Action Management Unit [CAMU] it may be attainable).

However, the majority of the waste that will be placed in the ERDF consists of LLW bulk soils. The question of whether this type of waste will need to be disposed of in a lined trench is currently under discussion with the regulatory agencies (U.S. Environmental Protection Agency [EPA] and Washington State Department of Ecology [Ecology]). Performance

Assessment (PA) modeling is being performed to evaluate the relative benefits of various types of liner systems, cover systems, and methods of waste treatment (WHC 1993c). The PA study will provide a technical basis for determining if a liner system will be required for all waste types.

If unlined trenches are allowed for LLW, they will be employed at the ERDF for two primary reasons. First, they will be significantly less expensive to construct than lined trenches. Second, because they can be constructed with steeper side slopes, unlined trenches will have a greater waste capacity per unit length and therefore occupy less land area. These issues are quantified in Section 6.

Alternatively, for LLW only, it may be technically feasible to employ a liner system that provides an adequate degree of protection during landfill operations but is not as complex as the full RCRA liner system. An example of this approach would be a single impermeable geomembrane topped with a leachate collection system. The advantage of a single liner system is primarily cost. This option is also being evaluated as part of PA and regulatory negotiations.

A summary of capability of potential lining systems for the base case trench configuration to satisfy various evaluation criteria is presented in Table 1. Issues of general concern to the public relate to health protection, environmental protection, and cost. Potential regulatory issues relate to RCRA minimum technology requirements for liner systems, either directly or as Applicable or Relevant and Appropriate Requirements (ARARs), DOE dose limits, and performance criteria if the ERDF can be permitted as a CAMU. In addition, the nine factors evaluated for Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remediation under the National Contingency Plan (NCP) are evaluated. Cost estimates are presented in Appendix A.

In summary, while RCRA minimum technology requirements would not be satisfied by a single lined or unlined trenches, PA modeling to date suggests that all liner systems are capable of limiting health risks to very low levels and that differences among the liner systems are not significant. This reflects the fact that the operational period is very short and that the Hanford Barrier is the controlling component for contaminant release after closure. Costs and surface area requirements are substantially less for unlined trenches than for either single or double lined trenches.

2.1.2 Radiation Level of Waste

Waste will be classified as either CH if the radiation level at the waste or container surface is less than 200 millirems per hour (mrem/hr) or RH if the radiation level exceeds this value. Two aspects of exposure are considered: worker exposure during ERDF operation and public exposure after facility closure.

Dose limits for landfill workers are limited by DOE Order 5480.11 *Radiation Protection for Occupational Workers* to no more than 500 millirems per year (mrem/yr). This limit will be achieved by: (1) using overpacks around RH waste containers to reduce the radiation level, (2) placing RH waste with equipment that limits worker exposure by distance or shielding as required, or (3) a combination of methods. RH waste will be covered with soil at the earliest feasible time after placement in the trench to reduce direct radiation exposure. With this approach, no difference in the type of trench is necessary and both RH and CH waste will be disposed of in the same trench. The transportation systems may be different with bulk soils being placed either by conveyor or dumped from a truck and single-use/disposable containers delivered by truck and off-loaded in a separate area of the trench. It is currently not expected

Table 1. Evaluation of Potential Liner Systems.

Criterion	Double-Lined Trench (RCRA)	Single-Lined Trench	Unlined Trench
(1) Public Concern Issues			
• Minimize area required for ERDF	1,576 acres	1,576 acres	788 acres
• Avoid disturbance of old-growth sagebrush	Proportional to area	Proportional to area	Proportional to area
• Minimize costs ^a	\$ 1,349,000,000	\$ 1,168,000,000	\$ 552,000,000
• Minimize risk to human health and the environment ^b	Less than 10 ⁻⁹	Not evaluated by Performance Assessment Modelling	Less than 10 ⁻⁹
(2) Potential Regulatory Requirements			
• RCRA Minimum Technology Requirements for Landfills (40 CFR 264.301, WAC 173-303-665)	Yes	No	No
• DOE Dose Limits to the Public and the Environment (DOE Order 5820.2A)	Expected to comply ^c	Expected to comply ^c	Expected to comply ^c
• Corrective Action Management Unit Performance Criteria (40 CFR 264.552)	Expected to comply ^c	Expected to comply ^c	Expected to comply ^c
• National Contingency Plan (NCP) Evaluation Criteria (40 CFR 300.430) (CERCLA Criteria)			
- Overall protection of human health and the environment	Expected to comply ^c	Expected to comply ^c	Expected to comply ^c
- Compliance with ARARs	High	Medium to High	Medium to High
- Short-term effectiveness	High	High	Medium
- Long-term effectiveness and performance	Determined by Hanford Barrier performance	Determined by Hanford Barrier performance	Determined by Hanford Barrier performance
- Reduction of toxicity, mobility, and volume through treatment	Not Applicable	Not Applicable	Not Applicable
- Implementability	High	High	High
- Cost ^a	\$ 1,349,000,000	\$ 1,168,000,000	\$ 552,000,000
- State acceptance ^d	High	Unknown	Unknown
- Community acceptance ^d	High	Unknown	Unknown

Notes:

^aConstruction costs only which includes trench excavation, liner, and closure cover (Hanford Barrier).

^bIncremental cancer risk (ICR) related to groundwater at ERDF boundary at 10,000 years after closure (WHC 1993c).

^cPerformance assessment and/or risk assessment yet to be completed.

^dNot considered in initial selection alternatives in normal CERCLA process.

that single-use/disposable containers will be used. However, the analysis of the use of these containers is included in the study in case they are used. If all RH and hazardous/dangerous wastes were disposed in single-use/disposable containers, then less than 3 percent of the total waste volume would be so disposed.

Dose limits to any member of the public are limited to no greater than 25 mrem/yr by DOE Order 5820.2A *Radioactive Waste Management*. Because of access restrictions to the ERDF during the operational phase, this limit is a concern only at some time in the future when the Hanford Barrier has been installed over the trenches and the facility has been permanently closed. Since the thickness of the Hanford Barrier and foundation soil will be at least 15 feet, direct exposure is not generally considered an issue even if RH waste is placed at a relatively high elevation in the trench. Therefore, there is no need for a deeper trench configuration solely to accommodate RH waste. If exceptionally high-activity waste must be disposed of, it can be placed on the floor of the trench to take advantage of the shielding provided by the overlying bulk waste soil.

Dose to the public through the groundwater pathway also must be considered. The Hanford Barrier will control long-term infiltration rates and limit migration of contaminants to groundwater. The PA modeling described above indicates that neither the absence nor presence of a liner system substantially affects long-term performance at the groundwater table. If migration of certain contaminants is a concern, the most effective approach may be waste treatment (such as fixation). In any case, the solutions to the problem of long-term waste migration to groundwater do not involve altering the type or number of disposal trenches. Because there is no direct relationship between mobility and level of radioactivity, a single trench can be used for both CH and RH waste disposal.

2.1.3 Chemical Incompatibility

Incompatible waste is defined in the Washington State *Dangerous Waste Regulations* as follows:

" 'Incompatible waste' means a dangerous waste which is unsuitable for placement in a particular device or facility because it may corrode or decay the containment materials, or is unsuitable for mixing with another waste or material because the mixture might produce heat or pressure, fire or explosion, violent reaction, toxic dusts, fumes, mists, or gases, or flammable fumes or gases" (WAC 173-303-040).

Both Federal and State regulations prohibit uncontrolled mixing of incompatible wastes in disposal facilities:

"Incompatible wastes ... must not be placed in the same landfill cell unless [precautions to prevent reactions are taken]" (40 CFR 264.313).

State requirements are similar (WAC 173-303-665).

It should be noted that in this context, the term "landfill cell" refers to a specific area within a landfill that is separated from the remainder of the landfill by berms, clay backfill, or other type of physical and/or hydrologic barrier. It does not require an entirely separate waste trench.

At the ERDF, requirements for incompatible wastes will apply to hazardous chemical or mixed chemical and radioactive waste which will be disposed of in the RCRA-compliant trench

(see Section 2.1.1). Completely separate waste disposal trenches to isolate incompatible waste types will not be required for three main reasons:

- The regulations allow incompatible wastes to be placed in the same landfill provided they are segregated in separate cells. This approach is routinely employed at commercial hazardous waste disposal facilities. For example, the Envirocare facility in Utah, which accepts LLW and mixed waste for permanent disposal, separates incompatible wastes by a compacted clay barrier at least 2-feet thick (Peterson 1993a) and (see Appendix B). This is a relatively simple operational procedure which can be readily implemented at the ERDF.
- The types of wastes expected from Hanford site environmental remediation activities are not expected to contain incompatible chemicals. RCRA regulations include an example list of incompatible wastes (40 CFR 264 Appendix V; see Appendix C of this study). This list includes acids and alkalis, elemental reactive metals, organic solvents, hydrocarbons, cyanides, oxidizers, and similar materials that are reactive, corrosive, or flammable. Although potential waste streams for the ERDF have not been fully characterized, analysis of process data and limited sampling at several operable unit cleanup sites have identified the main expected chemical compounds. A typical example is the 100B Area and 100C Area, as described in the pre-design guidance document (Moore 1993). Based on available data, the potential and suspected contaminants of concern are shown in Table 2. Metals are in the form of salts, and the other inorganic compounds are relatively inert ionic species. Petroleum products are not expected to contain high levels of volatile (i.e., flammable) compounds. The pre-design guidance document states:

"The disposal history for the 100B Area and 100C Area operation does not indicate routine use or disposal of volatile organics."

For this type of waste stream, incompatible compounds are not expected. It should be noted that the substances in Table 2 were included on the basis of toxicological risk. Contaminant concentrations that produce health risks are generally expected to be orders of magnitude less than concentrations which cause incompatibility problems.

- Potentially incompatible wastes will be treated prior to disposal which will eliminate their incompatible characteristics. DOE Order 5820.2A *Radioactive Waste Management* requires that LLW containing hazardous wastes "shall also be regulated by the appropriate regional authorities under the Resource Conservation and Recovery Act". RCRA requirements include Land Disposal Restrictions (LDRs), which limit the types of waste that may be placed in landfills. As established in 40 CFR 268, a large number of hazardous wastes, including metals, organic solvents, and cyanides and other potentially reactive compounds, may be disposed in land facilities only if the waste has been treated to destroy or stabilize the hazardous components. Washington State *Dangerous Waste Regulations* further prohibit landfill disposal of free liquids, ignitable or reactive waste, solid acid waste, organic/carbonaceous waste (including hydrocarbons, solvents etc.), and leachable inorganic wastes (WAC 173-303-140). As with the Federal regulations, these waste types must be treated, and the treatment generally eliminates their incompatible characteristics. Remediation activities at the Hanford Site are expected to comply with LDRs. For example, the 100-B/C Area pre-design guidance document (Moore 1993) states:

Table 2. Potential Contaminants in the 100B Area and 100C Area (after Moore 1993).

Substance	Potential Contaminant ^a	Suspected Contaminant
Radionuclides:		
Carbon-14	X	
Cobalt-60	X	
Nickel-63	X	
Strontium-90	X	
Technetium-99	X	
Cesium-137	X	
Europium-152	X	
Europium-154	X	
Plutonium-238	X	
Plutonium-239/240	X	
Metals:		
Arsenic		X
Barium		X
Cadmium		X
Chromium		X
Iron		X
Lead	X	
Mercury		X
Nickel		X
Sodium		X
Zinc		X
Other Inorganic Compounds and ions:		
Asbestos	X	
Chloride		X
Fluoride	X	
Nitrate	X	
Sulfate		X
Organic Compounds:		
PCBs	X ^b	
Petroleum Products	X	

^aPotential contaminant: Detected during past sampling at concentrations which exceed background, exceed regulatory limits, and are toxicologically significant in accordance with EPA screening guidelines.

^bIf PCBs are present in sufficient concentrations, Toxic Substance Control Act (TSCA) regulations may apply.

Suspected contaminant: May be present based on process information and past sampling, but was not detected at concentrations sufficiently high to require classification as potential contaminant.

"All waste, except transuranic (TRU) waste, containing concentrations of RCRA LDR constituents will be further segregated for separate handling and processing."

and

"Equipment and facilities shall be designed to:

- Process organic waste constituents to meet RCRA LDR treatment limits
- Process all liquids such that no free liquids are transported to the 200 Area disposal site [the ERDF]..."

2.1.4 Summary

The issue of using unlined or single lined trenches for disposal of waste containing only LLW is presently being negotiated. The cost and required land area for unlined trenches are substantially less than for either of the lined trench alternatives while the degree of additional performance afforded by the liner systems is minimal. If unlined or single lined trenches are allowed, they will be allowed for LLW-only waste. RCRA-compliant lined trenches will be required for RCRA hazardous or mixed waste. In this case, a total of two major trench types will be required. If RCRA-compliant double liner systems are required for all waste types, then only one type of trench will be employed.

Radiation protection of workers and the public does not depend on the type or number of trenches, but rather on operational practices, closure cover performance, and/or waste treatment. Therefore, one trench can be used to dispose of both RH and CH waste. It was assumed that the RH-LLW and/or Category 3 will be disposed in single-use/disposable containers.

Significant quantities of incompatible wastes are not expected at the ERDF because they are not a large part of the waste inventory, and the incompatible characteristics will be largely eliminated by treatment to satisfy LDRs. If incompatible wastes are received, they will be disposed of in separate cells within the waste trench and isolated by soil or other barriers. Therefore, one RCRA-compliant trench can be used for all waste types.

Issues associated with long-term groundwater protection will determine whether one or two types of trenches will be used. The total number of trenches will, of course, be a minimum of one of each type; however, a greater number of trenches may be required by construction and operational considerations.

2.2 CONTAINERIZED WASTE DISPOSAL

2.2.1 Introduction

The disposal of containerized waste (single-use/disposable metal containers filled with waste material) is being considered as part of the waste disposal operation at the ERDF. These containers will contain less than 2.0 percent of the total volume of material disposed in the ERDF. The primary concerns are settlement (discussed in Sections 2.2.2 and 2.2.3), reactions between incompatible hazardous chemicals (discussed in Sections 2.1.3 and 2.2.4), and the leaching of active materials (discussed in Section 2.2.5). In order to conduct this investigation, the following assumptions were made:

1. Single-use/disposable containers were assumed to be rectangular and 18 cubic yards (yd³) in volume.
2. RCRA LDRs may require treatment of the wastes being received by the ERDF; consequently, reactivity will not be a concern. For this particular study, LDR treatment was assumed to not be required so that the most conservative method of operating this facility could be evaluated. Thus, it is assumed that some containers may contain reactive wastes.
3. In this section, it was assumed that incompatible wastes may be disposed in single-use/disposable containers. As described in Section 2.1, significant quantities of incompatible wastes are not expected so this is a worst-case, conservative assumption.

2.2.2 Settlement Considerations

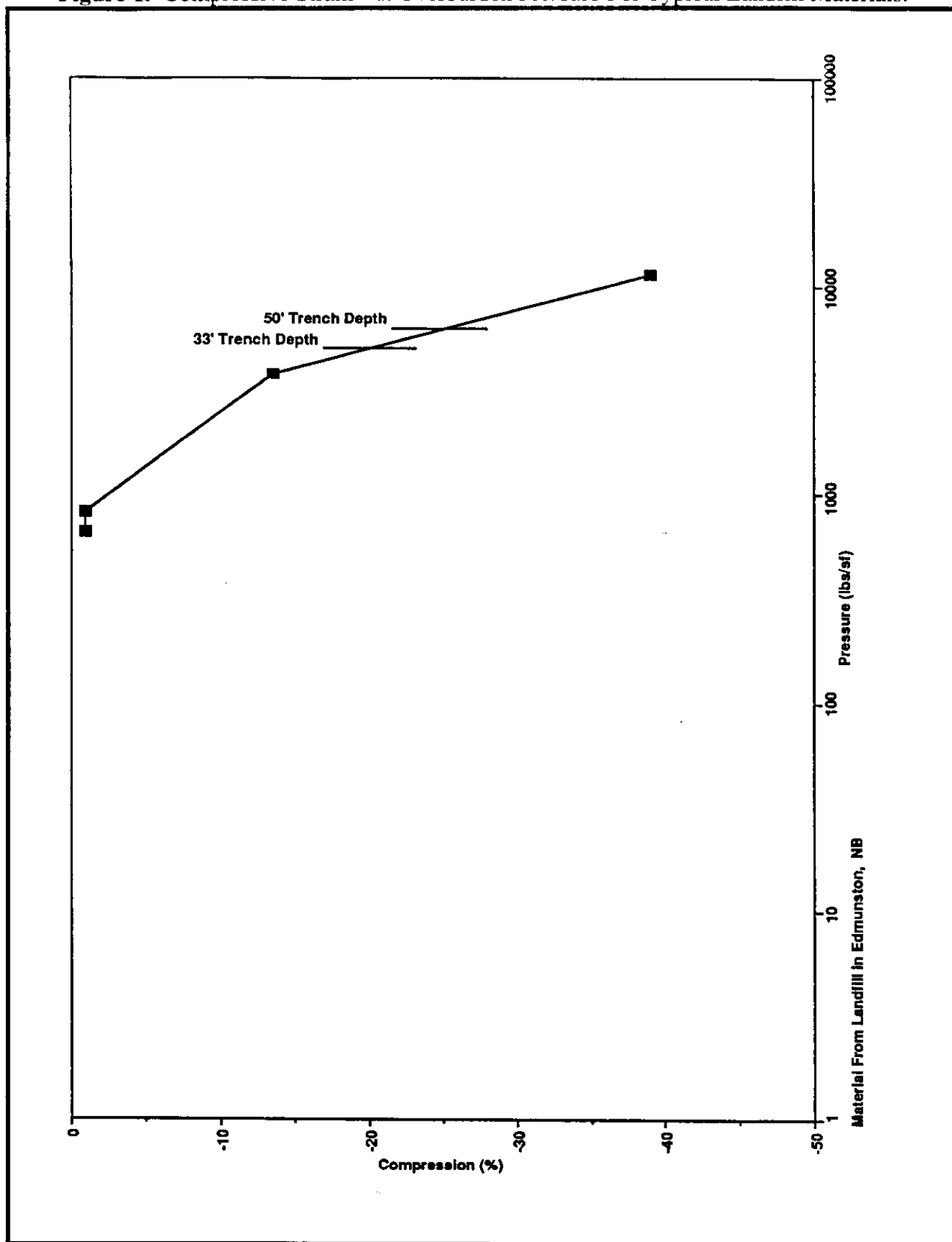
This report considers three mechanisms that affect settlement. These mechanisms are the crushing of the containers, the compressibility of the items in the container, and void spaces between containers.

2.2.2.1 Crushing of Containers. The single-use/disposable metal containers are stable in the short term but should not be relied upon for the life of the project. With time, containers buried in a landfill will corrode and lose structural integrity. Corrosion of containers is affected by soil type, chemical properties of the waste, the abrasive nature of the items in the container and container quality. Collapse of metal containers because of corrosion could vary over a wide period of time depending upon environmental conditions but has been estimated to be 7 to 14 years at the Sheffield, Illinois facility (Kahle and Rowlands, 1981).

Other related factors to consider are the damage to containers that may occur while placing the containers and damage to in-place containers induced by future dynamic compaction (if used).

2.2.2.2 Compressibility of Items Inside Containers. The items placed inside the containers and the manner in which they were placed affects the rate of settlement. Initially when a container is placed in a landfill, the container carries the overburden pressure. The overburden pressure is calculated by multiplying the overlying material depth by the unit weight of the overlying material. For example if the unit weight of the overlying bulk material is 105 pounds per cubic foot (lbs/ft³) and the trench depth is 33 feet plus 15 feet of cover, the overburden pressure is 5,632 pounds per square foot (lbs/ft²). Standard containers will be designed to support pressures of this magnitude but time, corrosion and other factors will cause the container to lose its structural integrity. When a container loses its structural integrity, the materials inside the container then carry the overburden load. Any void space within the container will be either filled with material from the soil (or waste) column above the container (which results in possible sink holes at the surface) or the void space is temporarily bridged by overburden (which poses future instability). Unless the items inside the containers have the strength to carry the overburden pressures, they will be compressed. Typical compressive indexes for landfill materials are shown in Figure 1 and indicate that substantial compression of that material is usually observed (Landva and Clark, 1990). Compression of items in containers could result in settlement at the surface.

2.2.2.3 Voids Between Containers. The last mechanism of concern is voids in the soil matrix between containers. Voids are created by bridging of soils and containers placed over voids.

Figure 1. Compressive Strain Vs. Overburden Pressure For Typical Landfill Materials.

With time, soil from the column above will migrate into the void and this movement will propagate through the column and result in settlements at the surface.

The container placement affects the size and frequency of the voids. The containers could be either randomly or regularly placed. Past experience has shown that random placement results in more bridging of soils (Tucker 1983). This report assumes that containers will be regularly placed to minimize voids (see Section 2.2.3.2).

2.2.3 Methods for Decreasing Total and Differential Settlement

2.2.3.1 Material Within Containers. The settlement of materials inside the container can be minimized by compaction of that material or by the addition of additives such as either grout or cement to fill voids and increase strength. Waste materials which consist principally of soils can readily be compacted and this is preferred to the addition of cement which is a more involved and costly process. Waste materials consisting of debris from the burial grounds can be compacted by super compaction equipment (similar to equipment tested at Oak Ridge National Laboratory (ORNL) (Rivera 1989) and Idaho National Engineering Laboratory (INEL) (Bohrer et al. 1987) or strengthened by filling voids in the waste with grout.

2.2.3.1.1 Compaction Required for Soil. Soil waste materials placed into containers for permanent disposal should be compacted to a minimum density which will support the weight of the overlying waste material and final cover without excessive settlement. This required density can be determined from correlations of density with elastic modulus and use of equations to determine the immediate settlement that will result once the load from the overlying soil and closure cover is applied. The immediate settlements for two conditions were evaluated. In the first case, the settlement of the height of soil in the container is compared with the immediate settlement of a similar element of soil adjacent to the container. The density of the adjacent soil is assumed to be dense for this first case. In the second case, the total settlement of the waste in the container plus the settlement of the waste above the container is computed and is evaluated based upon limiting the settlement at the surface to a 1 percent decrease in slope on the asphalt layer of the Hanford Barrier. The details of the analysis are shown in Appendix D. The equations and parameter values used in the evaluation are shown below:

$$S_i = \frac{\Delta s_v' H_0}{D}$$

where:

- S_i = immediate settlement
- s_v' = load from overlying waste and Hanford Barrier
(increase in vertical effective stress)
- H_0 = height of container or soil element considered
- D = One-dimensional modulus

The values for the elastic modulus were correlated with loose and dense granular soils respectively. Deformations were computed for loose, medium and dense gravel soils for both a 33-foot deep trench and a 50-foot deep trench, each with 15 feet of final closure cover (Hanford Barrier). The settlements computed were minimal for all cases. Based on these assumptions, compacting the soil in the container to a minimum of 105 lbs/ft³ will minimize settlement in the event the container collapsed. Also, it is assumed that the transport of the containers has generated sufficient vibration to preclude further settlement during earthquakes (see Laboratory Testing Program in Appendix E). These assumptions should be recomputed upon completion of the planned load/deformation testing of representative Hanford soils (which will provide site-specific modulus and density values) and final determination of the trench configuration. For

guidance, the contents of the containers should be compacted to the same level of compaction as the adjacent wastes.

2.2.3.1.2 Minimize Voids. Debris types of waste (such as those from the burial grounds) contain many voids which may result in settlement at the surface of the landfill following breaching of the container and migration of soil material into those voids. Stabilizing the wastes with a grout material is a common method used by waste generators and this appears to be the simplest and most cost effective way of eliminating voids in the type of wastes which will be removed from the burial grounds. Grout formulation testing at landfills in Sheffield, Illinois suggest that shrinkage of the grout can be minimized by adding clay material to the grout mix (Kahle and Rowlands, 1981). Even though the material in the container may have few voids and meet the required minimum density, some settling could occur during shipment or the container may not be completely filled. At US Ecology, Inc., maximum void space is limited to 15 percent for Class "C" waste. In order to minimize void space created by the transportation of the containerized material to the ERDF, it is recommended that testing be performed. Testing will consider container filling and compaction techniques to ensure that waste settlement is minimized.

2.2.3.1.3 Super Compaction of Debris. Super compaction of debris types of waste materials is an accepted waste processing technology that reduces the voids within the waste. This process could compact the waste materials to densities which could carry any overburden loading envisioned for this facility. But, this method has substantial costs and adds greater complexity to the waste processing system and is not recommended. Details of this process and its associated costs are discussed under the waste processing section (Section 3.1.4, Waste Processing).

2.2.3.2 Minimizing Settlement of Fill Between Containers. Materials placed around containers should be placed to minimize void space and increase soil matrix strength. For this study, soils are assumed to be placed from a conveyor belt that drops the soil from 30 feet (in Section 3.3.5, the use of placement machines that limit this drop to five feet are presented; therefore, the 30 feet of drop is a conservative assumption). This type of operation presents a greater opportunity for the formation of large voids (as compared with other operation scenarios) because the falling soil can easily bridge against the vertical side of the container and form voids.

The bridging problem can be minimized by placing the containers far enough apart to prevent bridging. This minimum spacing is demonstrated by the practice at US Ecology where the containers of waste are randomly placed 6 feet (two container diameters) apart then backfilled with dry sand. The dry sand flows around the containers and fills in the voids. Despite the bridging effects caused by the random placement of waste containers (random placement results in more bridging), the practice at US Ecology shows that local dry sands are fluid enough to fill the space between containers. Based on this fluid action that does not allow bridging to occur and engineering judgment of the behavior of dry sand as observed at the US Ecology site, it is recommended that the containers at the ERDF have a minimum distance of 2 feet between them and that local dry sands be used for backfill.

The containers should be placed within the trench in an orderly arrangement that allows easy access. Because the number of containers is small relative to the total volume of waste, it is suggested that the height of the containers be limited to that of a single container (no stacking). Limiting the stacking of containers will reduce bridging between containers and limit the effects of any settlement of the contents of the containers.

2.2.4 Reactivity Between Container and Surrounding Waste

The reactivity of materials released from a breached container is a potential concern associated with the placement of containers in bulk waste fills. Since the various possible types of wastes, their concentrations, and the conditions of placement are difficult to predict, predicting possible reactions is also difficult. One system of operation used by some waste management facilities is to review the reaction potential of all incoming shipments and then locate that waste adjacent to other waste where it will not pose a problem. At Envirocare, wastes placed in the trench are kept separate from wastes from other generators and the locations of the wastes are recorded. Incompatible wastes are separated by a barrier of at least 0.61 meters (2 feet) (Peterson 1993a). This practice is recommended for the ERDF.

2.2.5 Risk Associated with Breach of High Activity Containers

The breaching of radioactive waste containers is not a concern because the waste expected to be placed in the single-use/disposable containers does not have long half-lived radionuclides and the normal process of decay will reduce their potential as a health risk. Additionally, preliminary modeling indicates that none of the cancer-causing contaminants reach the ERDF boundary within 10,000 years; consequently, human exposure from groundwater contamination associated with a breach of a container is not a concern.

2.2.6 Summary

The main issues of concern when disposing of containerized waste within bulk waste are settlement and breaching of the containers which could release reactive substances. To minimize settlements, containers need to be spaced at least 2 feet apart to avoid soil bridging between containers and the containers should not be stacked. The materials within the container must have a high enough density through either compaction while inside the container or by addition of grout to support the overburden. As long as the materials in the container have sufficient strength to support the overburden and the void space within the containers is minimized, failure of the container is not a concern. Quality control at the remediation site will be required to verify that the container contents meet the above.

Reactive materials should be tracked and analyzed by qualified personnel to determine potential hazards. Incompatible wastes shall be separated by a barrier of at least 0.61 meters (2 feet). The breaching of radioactive waste containers, which could release reactive substances, is not a concern because the high activity waste, which is what would normally be placed in the single-use/disposable containers, generally does not have long half-lived radionuclides and the normal process of decay will reduce their potential as a health risk. Additionally, preliminary modeling indicates that none of the cancer-causing contaminants reach the ERDF boundary within 10,000 years; consequently, human exposure from groundwater contamination associated with a breach of a container is not a concern.

2.3 TRENCH OPERATION

2.3.1 Settlement Issues

2.3.1.1 Introduction. The primary purpose of the Hanford Barrier is to isolate contaminated wastes at the ERDF from surface water infiltration. As such, the long-term integrity of the Hanford Barrier is vital to the successful functioning of the facility. The Hanford Barrier and

allowable settlements are described in detail in the *Engineering Study for the Trench and Engineered Barrier Configuration for the Environmental Restoration Storage and Disposal Facility* (ERSDF) (COE 1993a). Excessive settlement of the waste materials could damage the Hanford Barrier, resulting in increased infiltration and leachate production. Two types of settlement are potentially serious:

- **Uniform Settlement:** settlement over a broad area that may reduce the final grade of the Hanford Barrier. A slope of 1 percent is considered the minimum necessary to provide adequate drainage within the Hanford Barrier. In the *Engineering Study for the Trench and Engineered Barrier Configuration for the ERSDF* (COE 1993a), analyses indicated that waste settlement should be no more than 3 percent to avoid unacceptable flattening of grades where the Hanford Barrier crosses the side slopes of the disposal trench.
- **Differential Settlement:** Non-uniform settlement occurring over a relatively short distance. In this case, overlying materials could undergo substantial shear strain and possible disruption. In the Hanford Barrier, such strains could damage or possibly breach the asphalt layer which functions as a moisture barrier. Even limited shear offsets or flexural cracking could form preferential pathways for infiltration. Although difficult to model, it is believed that shear displacements from differential settlements should be limited to a maximum of 1 or 2 inches (COE 1993a). Because most of the waste disposed in the ERDF is expected to be relatively uniform bulk soil, differential settlements would result primarily from long-term collapse of containerized waste. This issue is addressed in Section 2.2.

Considering that the ERDF is intended to provide permanent disposal and the uncertainties of long term settlement prediction, a conservative design for settlement of the Hanford Barrier is desirable.

2.3.1.2 Potential Settlement. The settlement components and laboratory testing program are described in Appendix E. The experimentally determined values for the Hanford soils are in agreement with general guidelines for these types of soils. This information provides reliability for the subsequent discussion on compaction.

2.3.1.3 Compaction Alternatives. As discussed in the *Engineering Study for the Trench and Engineered Barrier Configuration for the ERSDF* (COE 1993a), maximum allowable settlements to maintain sufficient grade within the Hanford Barrier to promote effective drainage are about 3 percent. The laboratory tests discussed previously indicated strains that may approach this value for initial loading if the soil is placed in a loose condition. Even larger strains of about 9 percent occurred when a loose soil was vibrated under low load. This latter test may simulate material delivered by conveyor system and stacked in the waste trench without further compaction. It may also represent bulk waste dumped directly from trucks. In any case, the laboratory testing results indicate that some type of compaction will probably be necessary prior to constructing the Hanford Barrier.

Based on engineering experience, mechanical densification is considered the most practical means to reduce settlements at the ERDF site. Mechanical densification can be either preloading and surcharging, which is used for cohesive soils, or mechanical densification which is used for looser or granular soils.

Preloading and surcharging techniques, in which a static load is applied over the fill at the ground surface, are commonly used to densify clay soils and reduce subsequent settlements. However, granular soil deposits cannot ordinarily be densified using surcharge fills. Although some secondary settlement may occur, vibration is generally necessary to disrupt the soil

structure and allow it to move into a denser condition. This was observed in the laboratory testing discussed above, where settlements of almost 10 percent were observed. Hence, surcharging is not considered reliable for use with ERDF waste because significant settlement could occur from future vibrations such as seismic tremors. Although not considered a highly active area, southeastern Washington has experienced moderate (magnitude 5.7) earthquakes within historical times (Algermissen 1983).

Densification of loose, cohesionless soils is usually accomplished using dynamic methods. Common techniques of dynamic soil densification are:

- Deep Blasting
- Dynamic Compaction
- Vibrocompaction
- Vibratory Rolling

The first three of these techniques will be applied from the ground surface after the trench has been filled with waste. Vibratory rolling will be performed as the waste is placed either by truck or by conveyor system. Each of these techniques is briefly discussed in the following paragraphs.

Deep Blasting. Deep compaction by detonation of buried explosives can provide a rapid, low cost means for soil improvement in some cases, provided that the soil is saturated. Soil densification is accomplished by a liquefaction process, where a large sudden compression wave causes an immediate build-up in pore pressure. This wave is followed by a shear wave which is responsible for failure of the mass. Typically, the compaction zone extends many feet from the blast location.

Blast densification is not a viable approach for the ERDF because the waste will not be saturated. In addition, there is a high potential for damage to the underlying liner structures.

Dynamic Compaction. Dynamic compaction (or "heavy tamping") involves the repeated dropping of heavy "pounder" weights onto the ground surface. The pounder may be a concrete block, a steel plate, or a steel shell filled with concrete and may weigh from 1 to 200 tons. Drop heights may be as high as 100 feet. The depth of significant compaction generally varies with the square root of the pounder weight and the drop height (Leonards et al. 1980). Densification is induced by a large shock to the soil structure which allows the particles to form a more compact configuration.

Dynamic compaction is not considered suitable for the ERDF because of the problems of fugitive dust generation and the unknown effect of impacts on underlying liner structures. Also, in fills deeper than 20 or 30 feet deep, this method may have limited effectiveness and produce uneven compaction, which could lead to differential settlement.

Vibrocompaction. Vibrocompaction methods are characterized by the insertion of a cylindrical or torpedo-shaped probe into the ground. Soil compaction is then achieved by vibrating the probe during withdrawal. In some methods, granular backfill is added to the open hole so that a compacted sand or gravel column is left behind upon removal of the probe. Sinking of the probe to the desired treatment depth is usually accomplished using vibration methods, often supplemented by water jets at the tip. Vibrocompaction methods are best suited for densification of clean, cohesionless soils. Experience has shown that they are generally ineffective when the percentage by weight of fines (passing U.S. #200 sieve) exceeds 20 percent to 25 percent (Mitchell 1981).

Brief descriptions of the four most common vibrocompaction methods are given below (Mitchell 1981):

- **Vibrating Probes:** Piles, probes, or rods are driven into the soil by a vibrating pile driving hammer. Several cycles of insertion and withdrawal are typically used in the densification process. This approach has been evaluated experimentally at the Hanford site and appears to be potentially useful (COE 1993a).
- **Vibroflotation:** In this case, the probe (called a "vibroflot") is a hollow steel tube containing an eccentric weight mounted on a vertical axis to provide a horizontal vibration. The vibroflot is jetted into the soil using water. Because of the potential for increased leachate production, this method is not considered suitable for use at the ERDF.
- **Vibro-Composer Method:** A casing pipe is driven to the desired depth by a vibrator at the top. Sand is then introduced into the pipe while it is vibrated and slowly withdrawn to the surface. A densified sand column is left behind in addition to the surrounding compacted in situ soil.
- **Soil Vibratory Stabilizing Method:** This method combines both the vertical vibration of a vibratory driving hammer and the horizontal vibration of a vibroflot. Sand backfill is added from the ground surface into a cone of depression that forms around the probe. Water is not used in either the sinking or compaction process.

Vibrocompaction methods disrupt the soil structure in much the same way as dynamic compaction, except that the energy per event is many times smaller, the vibrations continue for a much longer duration, and the effects are felt to distances of a few feet from the source.

Advantages of vibrocompaction methods are that densification occurs under low-impact conditions which do not threaten the integrity of underlying liner structures, little dust will be expected (especially if the densification was performed through a clean soil blanket), and densification is uniform with depth at each probe location. The principal disadvantages of the methods are cost and complexity of application along with the non-uniformity of densification in the horizontal plane. This non-uniformity may lead to undesirable differential settlement of the Hanford Barrier between probe locations. It would not be desirable to use granular backfill soils with any vibrocompaction method because this would decrease the volume available for waste and would introduce structural heterogeneities into the fill.

Vibratory Rolling. As opposed to the previously discussed techniques in which soils are densified after the trench has been filled, ERDF waste soils could also be densified during placement. Heavy, smooth-drum vibratory rollers will be best suited for this task. Densification occurs due to cyclic deformation of the soil produced by oscillations of the roller. The roller characteristics (mass, size, operating frequency) influence the depth of compaction. Field tests are normally required to determine the density-depth relationship for a given roller, number of roller passes, and towing speed. Once the density-depth relationship is known, it can be used to determine the maximum permissible lift thickness to achieve the required minimum soil density (Das 1990).

Rolling during placement has significant advantages for the ERDF site: simplicity of operation, production of high soil densities which increase trench capacity, uniform densification in both the horizontal and vertical directions, and minimization of settlement potential. Rolling is also likely to be cost-effective compared to the previously discussed densification procedures applied from the ground surface. The main disadvantage of rolling is the potential need for

shielded or remotely controlled equipment to minimize worker exposure during placement of high dose rate waste if encountered (see Section 2.3.2).

2.3.1.4 Settlement Analysis. Based on the previous discussion, the following compaction alternatives are considered the most feasible and were evaluated in greater detail with respect to controlling settlement:

- Alternative 1. Waste soils placed loose, no compaction.
- Alternative 2. Waste soils placed dense using vibratory rollers.
- Alternative 3. Waste soils placed loose, vibratory probes used after trench is filled.

All compaction options were evaluated using the same assumptions concerning fill geometry, waste soil density and final surface grade. Settlement was calculated for the base case trench at points A, B, C (Figure 2) assuming no settlement of the liner and subgrade soils. These positions correspond to waste soil thicknesses of 0, 35, and 36 feet assuming a 2 percent slope on the waste surface. The Hanford Barrier is assumed to have an average unit weight of 125 lb/ft³ and thickness of 15 feet. This gives an applied stress due to Hanford Barrier construction of 1,875 lb/ft². Unit weight of fill soils were assumed to be 116 lb/ft³ for the loose fill case and 128 lb/ft³ for the dense fill case. It was also assumed that all immediate settlement due to the weight of the fill occurs during construction, and the only stress causing settlement of the Hanford Barrier is that due to the weight of the Hanford Barrier itself.

Compaction Option No. 1—Waste Soils Placed Loose, No Compaction. Placing the waste soils loose with no compaction prior to Hanford Barrier construction is the simplest method. Using incremental constrained moduli (incremental D values) from test 1 (see Appendix E), immediate settlement can be calculated by using Equation 1 and summing settlements for three-foot-thick sublayers of the fill. The calculations are presented in detail in Appendix E. Summarizing, immediate settlements are:

Position	Initial Height (feet)	Immediate Settlement (feet)	Immediate Settlement
A	0	0	0
B	35	0.26	0.75%
C	36	0.28	0.74%

Although these calculated immediate settlements are small, they may not reflect the actual settlement potential of a waste fill placed in the loose condition. This is evidenced by the 9.5 percent settlement observed when test 2 was densified from a loose condition. Large settlements were also observed when tests 2 and 3 were flooded and vibrated during loading. Therefore, prudent engineering judgment suggests that settlements of between 5 percent and 10 percent can be expected from a fill placed in the loose condition. On this basis, Compaction Option No. 1 is eliminated from consideration, and it is apparent that the waste soils placed in the ERDF trenches must be densified in some fashion.

Compaction Option No. 2—Waste Soils Placed Dense Using Vibratory Rollers. Densification using vibratory rollers during placement will bring the waste soils to a uniform medium dense condition. As a first approximation, an estimate of total fill settlement was made using incremental D values from test 2, which was conducted on an initially dense specimen.

Figure 1



Again, the trench fill was divided into three-foot-thick sublayers. The calculations are included in Appendix E. Summarizing, immediate settlements are:

Position	Initial Height (feet)	Immediate Settlement (feet)	Immediate Settlement
A	0	0	0
B	35	0.043	0.12%
C	36	0.044	0.12%

In addition to the above settlements, test 2 showed 0.18 percent strain when the specimen was flooded and vibrated at the 13,000 lb/ft² stress level. Thus, a conservative estimate of the combined immediate strain for the ERDF site is 0.30 percent. Using Equation 2 and a design life of 10,000 years, the long term secondary compression will contribute an additional 0.30 percent settlement. This value is considered to be conservative. Combining immediate strain and secondary compaction, Compaction Option No. 2 gives a total settlement over the life of the ERDF of 0.60 percent.

Because the fill is uniformly compacted during construction, potential for differential settlement is considered to be minimal.

Compaction Option No. 3—Waste Soils Placed Loose, Vibrocompaction Prior To Hanford Barrier Construction. In-situ densification, using vibrocompaction by piles or probes, will bring the average density of the fill to a condition in between that of Compaction Options No. 1 and No. 2. However, densification will not be uniform throughout the fill. Depending on the placement of compaction piles, soil density may range from medium dense to loose at any given location. Typically, each pile will be expected to have an effective compaction radius of about 3 to 10 feet (Mitchell 1981) and (COE 1993a).

A first estimate of total fill settlement can be made assuming that the following conditions apply: 1) half the soils undergo settlement similar to Compaction Option No. 2 and undergo 0.60 percent settlement, and 2) due to partial densification, half of the waste soils undergo settlement that is 50 percent of that suggested by Compaction Option No. 1 and undergo 4.25 percent settlement. Thus, the average total settlement is estimated as 2.4 percent.

It is important to have the pile spacing close enough to minimize areas of poor compaction. For example, an analysis of potential differential settlement was made based on the conservative assumptions that pile locations are placed 12 feet apart and that waste soils remain in their initial loose condition at the outer radius of each pile. The site is then regraded and the Hanford Barrier constructed. Calculations to predict differential settlement are not straightforward due to the unknown effect of soil arching. However, if soil arching is neglected, differential settlement could exceed 10 inches over a 12-foot span of the Hanford Barrier. Such settlement could damage the Hanford Barrier and will almost certainly produce low areas where moisture will collect. Thus, although this will likely be a conservative estimate, the possibility of unacceptable differential settlements cannot be ruled out for Compaction Option No. 3.

2.3.1.5 Summary and Conclusions

Laboratory test results indicate that compaction of some type should be performed to reduce the likelihood of unacceptable settlement. With respect to limiting both areal and differential settlement, use of vibrating rollers during waste placement is the preferred alternative. With this method, it is estimated that a total of 0.6 percent settlement will occur, thereby reducing the final grades only slightly from when the Hanford Barrier is placed. The advantages of this technique are:

- Uniform densification is achieved both vertically and horizontally, thereby eliminating potential differential settlement of the Hanford Barrier.
- According to laboratory test results, total settlement is expected to be less than 1 percent. This gives a safety factor of at least three with respect to the maintenance of the required final grades of the Hanford Barrier.
- Compaction procedures are simple and well-proven.
- High soil densities are achieved during construction which will increase trench capacity.

Field density tests will be required to determine lift thickness for adequate compaction for a given roller weight, size, operating frequency, and towing speed.

The main disadvantage of rolling is worker exposure if high dose rates waste is encountered which can be resolved through the use of remotely controlled equipment.

This study and the analyses presented herein are based primarily on a limited number of laboratory compression tests on a single soil type. Additional testing on other potential waste soil types should be performed to more completely determine settlement potential. Minimum and maximum density tests should be performed to indicate the total settlement that can be expected over indefinite periods of time. A well-designed field monitoring program should be performed during the early phases of ERDF operation to directly measure settlements as they develop during waste placement.

2.3.1.6 Compaction Costs

The unit costs for conventional (vibrating roller) compaction is estimated at \$120,000 per acre (includes waste spreading costs). For the 681-acre area fill trench A site (see Section 5.3), this is a cost of \$82 million. The unit costs for vibrating probe compaction are between \$85,000 and \$275,000 per acre. For the 681 acre site, the costs are between \$58 million and \$187 million. Appendix F contains the supporting information for the costs for the two compaction alternatives. The costs for vibrating probes are quite sensitive to probe spacing and the cost per linear foot of probe driving. It appears that vibrating probe compaction has a cost comparable to conventional compaction if the probes are spaced at 12 to 15 feet on center. However, if less favorable conditions are present, the cost of vibrating probe compaction could be substantially higher than conventional vibrating roller compaction. As presented in Section 2.3.1.5, the potential of excessive settlement is higher with vibrating probe compaction than with vibrating roller compaction equipment. Therefore, the use of vibrating roller compaction equipment is recommended.

2.3.2 Safety (Through Use Of Remotely Controlled Equipment)

Safety is a primary concern for design and operation of the ERDF. This section discusses the potential safety benefits from use of remotely operated equipment in comparison with the costs and operational restrictions associated with that equipment. The definition of CH LLW is waste material having a maximum radiation level at the waste surface of 200 mrem/hr. This report was written based on contact handling wastes of up to this level. The Safety Analysis Report (SAR) and Operations Plan could lower this limit significantly which would reduce potential safety concerns. Also one reviewer stated that based on the 100 Area Characterization Study, 727 of 734 soil samples had 25 mrem/hr or less dose rates (See Appendix I). Therefore, it is not expected that very much of the waste will be high dose rate material. However, the

potential exists that this material will be encountered so this must be taken into account. Ongoing waste analysis will determine if remote-controlled equipment is warranted.

2.3.2.1 Disposal Trench Equipment Operation Alternatives. Heavy equipment (dozers and compactors) used within the disposal trenches can be either manually or robotically controlled. If manual control is chosen, the cab will have to be modified to be air-tight and provide filtration of particulates. These hepa filters will be a maintenance problem and, if plugged, could cause dangerous conditions for the operator within the cab. Regular maintenance of these filters will be required. The cab may also need shielding. An escape mechanism would be required to ensure safe escape in the event of a breakdown or malfunction. This will be defined in the SAR.

Robotic or remote operation can be accomplished using available products at a relatively small cost. The operation center may be located either within the administrative facility or near the disposal trench. Remote control systems can be either permanently installed in the vehicle or may be removable.

2.3.2.2 Personnel Concerns and Restrictions. Personnel who have experience with the operation of heavy equipment in radioactivity contaminated work areas were contacted to determine their concerns regarding operation within the disposal cells. Personnel recommended that operations be handled from the top of the trench and they expressed concerns about the dust and radiation levels expected to be encountered. Changing of hepa filters was brought up as a major maintenance problem (Riley 1993).

2.3.2.3 Field Experience. There is a wide variety of experience with hazardous waste cleanup and disposal throughout the industry. A few examples are described below.

2.3.2.3.1 Demolition and Decommissioning (D&D) Experience at Hanford. Heavy equipment such as scrapers and backhoes are sometimes used in D&D activities involving radioactivity levels approaching 50 mrem/hr outside the cab. The burial grounds typically dispose of boxed or drummed material up to 100 mrem/hr. Operations around these levels are strictly monitored and restricted. In no case is a worker allowed to be exposed to these types of levels for an eight hour period under normal operations. The annual limit for WHC employees exposure at Hanford is currently set at 500 millirem (mrem) for normal operations (WHC 1993). With this limit and the expected levels of 50 mrem/hr, personnel will only be allowed to work in the ERDF trench approximately 10 hours per year which would require very large work crews.

2.3.2.3.2 Johnston Atoll Experience. Plutonium contaminated sands at Johnston Atoll were excavated, stockpiled, and transported to a conveyor hopper using heavy equipment (Moroney 1993). Equipment operators were equipped with powered, positive air pressure masks. The levels of radioactivity associated with heavy equipment operation such as a loader excavating from stockpiles of waste material have been observed to be low. The front end of the equipment accumulated higher levels of radioactive waste than the rest of the machine.

2.3.2.3.3 Envirocare Experience. Waste materials at Envirocare are routinely placed and compacted by manual equipment with operators in anti-contamination clothing and respirators. The levels of radiation in these manually handled wastes are normally around 60 to 70 microrems per hour. The operators of this equipment typically receive around 30 mrem per quarter which is about one half the Hanford quarterly dose. Since the expected ERDF radiation levels are up to 1,000 times higher than Envirocare, the quarterly doses received by the operator for this type of operation would be unacceptable at the ERDF.

2.3.2.3.4 Explosive Ordinance Disposal (EOD) Team Experience. The Teleoperated Remote Controlled Excavator (TORCE I), began operation at an Air Force base in March, 1987. The EOD team used the system on a routine basis to excavate and recover unexploded munitions

for inspection. The EOD team objective was to retrieve live pre-triggered explosive devices intact for failure analysis while remaining safe from harm. The EOD team changed personnel during the period of operation and found that new people were readily trained. The excavator functioned reliably and effectively in its assigned role. The EOD team was enlisted to evaluate its use in cleanup activities at the Milan, Tennessee Army Ammunition Plant in the summer of 1987. At conclusion of the operation, the team had excavated 64 sites to an average depth of 18 feet for the USACE. This operation took approximately 84 machine hours or about half the time originally scheduled to complete the project. The engineer in charge of the project estimated that the cost savings associated with using remote controlled excavation as compared to manual excavators was 30 to 40 percent (Wohlford et al. 1987).

2.3.2.4 Remote Feasibility. Robotic or remote operations are becoming increasingly popular and available. Both John Deere and Caterpillar have provided remotely operated equipment for various types of jobs. Vectran Corporation in Pittsburgh, Pennsylvania and Blackbox in Ontario, Canada supply remote operation systems and can modify existing or newly purchased equipment on site.

To convert a standard D-8N Caterpillar dozer to remote operation, a number of alterations must occur. The hydraulic systems must be modified to accept remote control. High-performance servovalve components are used to improve dexterity, hydraulic pressure sensors provide indications of force exerted, position encoders aid robotics, and color television cameras provide remote viewing capabilities. Conversion of a 824C compactor to remote operation works on the same principle, but is considerably less complicated.

On-board operators at hazardous sites are typically required to wear fully encapsulated life support systems and then work for only short intervals. The reduced capacity, downtime, and multiple crews needed to support operations are unnecessary with remote control.

A wide variety of remote control systems are available, from the completely automated to complete manual operation at the remote site. For the application at the ERDF, complete automation would cost significantly more and would require additional maintenance. If the equipment were to become contaminated and require disposal, the replacement cost would be significant. Manual remote operation, however, provides reliable service and capital expenditures are reasonable.

2.3.2.5 Remote System Description. There are a variety of remote operation systems available, but one of the most commonly used systems is described below.

The Vectran VR10 digital radio remote control system for a D-8N Caterpillar type dozer includes:

- One portable control transmitter with the following features and functions:
 - One 2-axis joystick to control direction of travel and brakes. Turns are accomplished by applying either brake independently. The speed of the turn can be increased or decreased by the throttle. Controls allow a sharp turn mode.
 - One 2-axis joystick to control blade functions: raise, hold, lower, tilt right, tilt left, and float.
 - Transmission neutral, first gear forward, and first gear reverse.
 - Throttle: operator can advance throttle from idle to full power. At reaching desired engine speed it will maintain that selection until operator changes setting.
 - Remote start and reset.
 - Remote emergency stop applies break and selects neutral gear.
 - Remote shutdown stops engine.

- Kew switch transmitter renders the remote control operator station inactive until activated by the proper key.
- The remote control station weighs less than 50 pounds and is contained in a sealed stainless steel case.
- The remote control operator station can operate for eight hours on a set of rechargeable batteries or can be connected to a 24 volts (V) direct current (DC) or 110/220V alternating current (AC); 50 or 60 hertz (Hz) source for continuous operation and/or battery charging.
- Low battery indicator.
- Tractor mounted equipment as follows:
 - Digital radio receiver/decoder with 72-76 or 450-470 megahertz (MHz) operation. Range is 5,000 feet by wireless radio transmission and 1,000 feet by coaxial wire cable.
 - Four color status lights to be activated by the Caterpillar monitoring system. Lights will mimic existing warning signals: oil pressure, water temperature, etc.
 - Hydraulic interfacing of brakes and controls.
 - Receiver in National Electrical Manufacturer's Association (NEMA) 12 enclosure (environmentally sealed).
 - Antenna line kit and mounting hardware.
- Close circuit television cameras and associated hardware.
- Associated items include the following:
 - Engineering of radio to dozer.
 - Two NC100 nickel cadmium batteries.
 - One BC100 battery charger.
 - Two sets of blueline and one set of reproducible drawings.
 - Three operator/maintenance manuals.
 - Installation turnkey at Washington site.

Equipment utilizing this system can be operated in a variety of ways. The manual controls on the equipment are not removed, so if conditions permit, the equipment can be operated manually. If conditions allow, the system could be used at the edge of the trench with direct line of site. An experienced equipment operator can control the equipment and the depth of the blade quite well if the equipment can be observed. Complete remote operation of equipment is through equipment mounted cameras and a pedestal mounted camera for overview. Grading to tight tolerances can be accomplished by using a mechanical indicating system such as a pointer arm rigged to the blade arm. The camera can tilt to this pointer and relay the blade height immediately to the operator. This allows accurate placement of the top cover. An equipment operator can control the depth of the blade quite well if provided with visual and audible feedback along with blade height indicator. The overall visual view of operations is valuable in avoiding accidents with other equipment and to get a feel for the general location of the equipment.

2.3.2.6 Limitations of Remote Control Systems. Recent remote control designs typically duplicate the relative locations of equipment manual controls. The removal of the operator from the cab, however, results in loss of sensory inputs from tactile and vibration sources. Although two cameras are mounted on the equipment and one additional camera provides an overview, the visual feedback is significantly reduced. The result of this is reduced productivity when engaged in conventional earthmoving. However, the productivity increases substantially when compared to alternatives operating in hazardous environments. Learning to operate remote controlled

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 - Installation turnkey at Washington site.

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equipment from a remote station appears to be readily accomplished by totally unfamiliar operators and is only slightly more time consuming for operators that are accustomed to a full range of sensory information. Very high levels of productivity can be achieved with practice (Wohlford et al. 1987).

2.3.2.7 Capital Costs for Equipment. A standard Caterpillar D-8N dozer costs the government approximately \$260,000 and a 824C compactor costs approximately \$210,000. The addition of a remote operation system onto the equipment costs approximately \$80,000 for the dozer and \$50,000 for the compactor. This additional cost is fairly small compared to the liability of the workers. In addition to the additional equipment costs, a work area must be set up. This area may be located in a trailer mounted at the top of the trench.

2.3.2.8 Recommendations. Remote operation of all in-trench equipment is recommended as conditions warrant. The SAR and Operations Plan will set these conditions. Ongoing waste analysis will help determine if remote-controlled equipment is warranted. The additional capital cost associated is relatively small and the safety is greatly improved. These products are available as a custom product from manufacturers, therefore, additional research and expenditure on the part of DOE is not needed.

2.3.3 Gas Generation

There will be some trash and other decomposable materials placed in the ERDF. Preliminary estimates indicate that approximately 4 percent of the material from the burial grounds is decomposable (buried waste) (Section 3.1.3.4). If significant quantities of these materials are present, anaerobic conditions could produce methane gas that could cause odor and explosion concerns. Since the vast majority of the material that will be disposed will be soils and other non-decomposable materials, and since the decomposable materials will be either distributed throughout the mass fill or stabilized inside single-use/disposable containers, gas generation is assumed to be negligible.

2.3.4 Groundwater Protection

Protection of the groundwater to eliminate human health risk due to exposure to contaminated groundwater is extremely important. Because the area fill method of disposal will concentrate the waste in a smaller area, groundwater contamination may vary from conditions associated with conventional disposal trenches. This case is currently being modeled as part of a different study. Preliminary results of that modeling suggests that the exposure associated with the area fill trench configuration will not be significantly different from conventional trenches (Kindred 1993). Contaminants migrating from the area fill trench have approximately 10 to 15 percent faster travel rate and 10 to 15 percent higher concentration at the boundary of compliance (the groundwater at the ERDF boundary) as compared with the conventional trenches. The higher values are the result of less dilution of the contaminants by infiltration of water from areas outside (adjacent) to the trench and because the area fill used in the model had a 30-meter (98.34 feet) depth. The 30-meter (98.34 feet) depth is deeper than any area fill trench currently envisioned (these range from 10 meters [32.81 feet] to 21 meters [68.90 feet] in depth). Given the uncertainty of the long-term performance of either the area fill or conventional trenches, there is no significant difference between the two designs in terms of groundwater contamination.

2.3.5 Summary

Laboratory test results indicate that compaction of some type should be performed to reduce the likelihood of unacceptable settlement. With respect to limiting both areal and differential settlement, use of vibrating rollers during waste placement is the preferred alternative. With this method, it is estimated that a total of 0.6 percent settlement will occur, thereby reducing the final grades only slightly from when the Hanford Barrier is placed. The advantages of this technique are:

- Uniform densification is achieved both vertically and horizontally, thereby eliminating potential differential settlement of the Hanford Barrier.
- According to laboratory test results, total settlement is expected to be less than 1 percent. This gives a safety factor of at least three with respect to the maintenance of the required final grades of the Hanford Barrier.
- Compaction procedures are simple and well-proven.
- High soil densities are achieved during construction which will increase trench capacity.

Field density tests will be required to determine lift thickness for adequate compaction for a given roller weight, size, operating frequency, and towing speed.

The main disadvantage of rolling is worker exposure which can be resolved through the use of remotely controlled equipment.

This study and the analyses presented herein are based primarily on a limited number of laboratory compression tests on a single soil type. Additional testing on other potential waste soil types should be performed to more completely determine settlement potential. Minimum and maximum density tests should be performed to indicate the total settlement that can be expected over indefinite periods of time. A well-designed field monitoring program should be performed during the early phases of ERDF operation to directly measure settlements as they develop during waste placement.

Remote operation of all in-trench equipment is recommended. The additional capital cost associated is relatively small and the safety is greatly improved. These products are available as a custom product from manufacturers, therefore, additional research and expenditure on the part of DOE is not needed.

Gas generation from decomposing waste is not expected to be a problem.

Preliminary results of the groundwater modeling suggests that the exposure associated with the area fill configuration will not be significantly different from conventional trenches.

3.0 CONVEYING OF WASTE MATERIAL

In an earlier report (COE 1993c), the transportation of waste material by truck was presented. Truck transport requires a number of drivers to operate the trucks and these drivers could become affected by the LLW. In this section, the use of mechanical conveyors to transport the waste is presented. Due to certain limitations associated with the conveyor system, the conveyor cannot handle all the waste. These limitations are presented in Section 3.1, Waste Acceptance Criteria.

This study was directed to investigate other means of rail transportation of the waste to select the best system for use with the mechanical conveyor alternative. This included both the use of rail cars (Section 3.2.2) and the use of liners or sacks (Section 3.2.3).

The mechanical conveying system is described and the components developed in Section 3.3, Mechanical Conveying Components. Section 5 of this report compares truck transport of waste to mechanical conveying of the waste.

3.1 WASTE ACCEPTANCE CRITERIA

3.1.1 Introduction

The waste acceptance criteria for bulk material were developed by considering the material handling limitations of various components that make up the conveyor transportation system considered in this study. Those limitations were matched with waste-processing systems to determine if the waste acceptance criteria could be made less restrictive by incorporating additional waste-processing systems. The limitations associated with the combined conveyor and waste-processing system were used to determine the waste acceptance criteria.

Section 3.1.2, Conveyor Transportation System Component Limitations, identifies the types and sizes of waste which will result in excessive wear or operational problems for the potential conveyor transportation system components. In Section 3.1.3, Waste Material Types, the types of waste that could be of potential concern (because of abrasiveness, hardness, or size) will be quantified. Section 3.1.4, Waste Processing, discusses the types of waste processing equipment that are available, the problems and limitations of that equipment considering the types of waste anticipated to be received by the ERDF, and selects a processing system based upon economic, operation, and safety considerations. The recommended waste acceptance criteria is summarized in Section 3.1.5, Recommended Waste Acceptance Criteria based upon the system selected in Section 3.1.4.

This evaluation is for CH LLW. All other wastes will be handled as described in Section 3.3.8, Transportation Of Materials Not Within Bounds Of Normal Case.

3.1.2 Conveyor Transportation System Component Limitations

3.1.2.1 Introduction. The conveyor transportation system considered in this study will consist of rail road flat cars carrying containers of waste from the operable unit remediation to the ERDF loading/off-loading facility. The containers will be off-loaded from the rail cars and emptied into a hopper that will feed the waste processing system. The oversized material will be removed by a 6-inch grizzly. The grizzly screened material will be conveyed to vibratory screens where the

objects larger than 10 millimeters (mm) in size will be removed. The smaller waste will be transported by conveyor to the agglomerators to mix with dust surfactants. From the agglomerators, both the agglomerated waste and the waste removed by the vibratory screens will be combined and carried by conveyor belt to the disposal trench.

Each component of this system has specific limitations on the types and sizes of material that can be accommodated with respect to damage and wear. These limitations are discussed in the following sections.

3.1.2.2 Acceptance Criteria Associated with Rail Cars. The transportation concerns associated with hauling large objects in containers on rail cars is the responsibility of other design groups and is not within the scope of this study. But, consideration of gondola rail cars, rotary couplers, and other alternate transportation means are considered in this study and acceptance criteria associated with those conveyances are identified in this section. Various rail cars, such as the rotating coupler, may require cross members to provide additional structural support to avoid failure from day to day transport of large, heavy objects. The maximum size of material which may be loaded into the rail cars without excessive wear varies with the type of loading operation (for example dropping large heavy objects from a loader bucket several feet above the car will damage the car more than if the same size objects were carefully placed into the car using a crane or backhoe). As a general rule, the maximum size should be restricted to 3 feet in diameter.

3.1.2.3 Acceptance Criteria for Agglomerator. The size and type of materials that cause excessive damage or wear for agglomerator equipment depends to a large degree upon the size and individual characteristics of the equipment. Agglomerators having sufficient capacity to accommodate the volume of waste that will be received by the ERDF will suffer excessive wear and decreased effectiveness when object sizes exceed 1 inch in diameter. The agglomerator is most effective in controlling dust if it receives only 10 mm and smaller materials. Additionally, long objects (in excess of 3 feet) can become wedged inside the agglomerator and result in plugging.

3.1.2.4 Acceptance Criteria for Conveyor. The conveyor belt for transportation of the waste material from the agglomerator to the disposal trench is assumed to consist of a 48-inch wide multiple, rubberized belt (Bader 1993). Based upon experience with other similar sized conveyor systems, the maximum sized object that will not present excess wear, spillage and clogging problems at transfer points is 6 inches (Bader 1993, Palmer 1993, and Gibson 1993). Wear may be accelerated by sharp objects, ragged edges, and abrasive materials. Removal of sharp metals and other abrasive materials may be warranted if it can be accomplished in a safe and cost-effective manner.

3.1.2.5 Summary. A maximum object size of 6 inches will protect the conveyor belt and associated transfer points. Material entering the agglomerator must be restricted to 10 mm in size to optimize that equipment. The 6-inch and 10-mm size restrictions can be provided by a number of different systems (crushing, separation, or shredding) and these systems will be evaluated further in section 3.1.4, Waste Processing.

3.1.3 Waste Material Type

3.1.3.1 Introduction. The object size and type of waste material to be disposed of at the ERDF will present specific handling and processing concerns depending upon its characteristics (size, hardness, abrasiveness, etc.). These characteristics are reviewed in this section to aid in determining processing and material handling requirements. Soil throughout the waste sites located in the 100 Area and 300 Area, debris from burial grounds in the 100 Area, and D&D

wastes are expected to be excavated and placed in the ERDF over the life of the facility. The expected total volume of material is 28.5 million yd³. For the years 1997 through 2001, 86 percent of the wastes are expected to be overburden and soil (see Table 3). This percentage of soil was calculated from information provided in the *FUNCTIONAL DESIGN CRITERIA* (FDC) *ERSDF Project W-296* (WHC-SD-W296-FDC-001, Rev 1).

3.1.3.2 100 Area Burial Sites. In order to develop a general understanding of the debris expected to be encountered in the 100 Area burial grounds, the report "Estimates of Solid Waste Buried in the 100 Area Burial Grounds" (WHC 1987) was closely examined. In addition to examining this report, telephone conversations and inspector logs of burial ground 105 B were used to develop a general overview for all of the burial grounds.

3.1.3.2.1 Primary Burial Grounds. The 100 Area has 7 primary burial grounds that were used for routine reactor operations. These burial grounds contain the majority of the waste from routine reactor operations. From information provided in WHC document *Estimates of Solid Waste Buried in 100 Waste Burial Grounds* (WHC 1987), it was determined that 59 percent by weight of debris would be metal and 99.9 percent of this debris would be larger than 6 inches. Also, as indicated in the report, 75 percent by volume and calculated 41 percent by weight would be soft waste. Soft waste would include plastic, paper, and clothing packaged in cardboard cartons.

3.1.3.2.2 105 B Burial Ground. A breakdown of the materials in 105 B burial ground, as indicated from the log book, is shown in Table 4. The following discussion describes the material listed in Table 4. Information for this discussion was taken from three main sources. These sources are Westinghouse document *Estimates of Solid Waste Buried in 100 Waste Burial Grounds* (WHC 1987), a phone conversation with Dick Winship of Westinghouse (Winship 1993) and the document *Summary of 100-B/C Reactor Operations and Resultant Wastes, Hanford Site* (WHC 1993a). Most of the measurements are approximated. A summary of the waste types is as follows:

- Trash consists of contaminated paper, plastic, clothing, etc., which usually were disposed of in cardboard boxes of unknown size.
- Perforated spacers and dummies, for practical purposes, can be classified as the same size and doing the same type of functions. Perforated aluminum spacers centered the reactor fuel column in the process tube and kept fuel elements in place during operation. They were 8-inches long with a diameter of 1.4 inches and weighed 0.5 pounds. "Perfs" are tubular lengths of perforated aluminum that are placed downstream of the dummy charges. Dummies are used in place of fuel elements. The majority of the dummies were made of lead but initially a few were made of wood.
- Poison refers to a lead-cadmium alloy which was used to neutralize the reactivity of hot spots in a reactor. It is in the form of a 6-inch long solid rod with a 1.4-inch diameter and weighed 3.36 pounds. "P" is another term used for reactor poisons.
- Lead commonly came in the form of bricks, sheets, wool, and casks. The most common form is a 6-inch, 25-pound standard brick.
- Thimbles were used in the horizontal control rod (HCR) and vertical safety rod (VSR) channels to provide a sealed access to the reactor for the control and safety rods and for a boron solution used as a third shutdown device (WHC 1987). A thimble was

Table 3. Phase I, Waste Projection for Years FY 1997 - FY 2001 after WHC (1993b).

Waste Type	Cubic Yards of Waste by Waste Form						Total Waste Type	Percent Total Type
	Over-burden	Soil	Metals	Buried Waste	Demolition	Decommission		
Contact Handled LLW - Cat 1	2,290,100	2,755,700	247,300	174,700	277,100	15,200	5,756,200	95.8
Remote Handled LLW - Cat 1	1,900	15,700	1,200	10,800	1,300	600	31,500	0.5
Non Hazardous - Non Rad	0	0	4,500	10,800	27,200	0	42,500	0.7
Contact Handled, Mixed LLW - Cat 1	2,700	64,400	5,900	30,200	2,100	0	105,300	1.8
Remote Handled, Mixed LLW - Cat 1	1,900	15,700	1,200	10,800	1,300	0	30,900	0.5
Hazardous/Dangerous	2,000	25,400	2,200	10,800	2,700	0	43,100	0.7
Total Waste Form	2,298,600	2,876,900	262,300	248,100	311,700	15,800	6,009,500	100.0
Percent of Total Waste Form	38	48	4	4	5	1	100	
Percent of Non Overburden and Non Soils Material	NA	NA	31	30	37	2	100	

Table 4. Hanford Burial Inventory (Taken From Original Log Book).

General Material	Specific Material	Amount (number)	Units	Description of Size or Unit Weight
Trash		21	boxes/buckets	cardboard cartons
Dummies	Wood	105	units	unknown
	Lead	728	units	364 pieces=1,300 pounds
	Unknown	10	buckets	unknown
Wood	Plywood, posts, lumber, etc.	32	times mentioned	unknown-objects vary
Pipes and tubes	Short	13	units	unknown
	Long (process tubes)	3,309	units	40', but chopped into 3'-5' foot lengths, 1.9" dia.
Vertical safety rod (VSR)	Guides	13	units	unknown, but made of boron
	Tips	13	units	unknown, but made of boron
	Rods	10	units	unknown, but made of boron
Underwater	Scoop	1	unit	unknown
	Chamber	10	units	unknown
Thimble (aluminum)	Junk (light, mirror, etc.)	5		unknown
	Piece	2	units	35' long, 3.5" diameter, 90 pounds
Miscellaneous metals	Sections	4	units	unknown
	Pumps	13	units	unknown
	Signs	1	batch	unknown
	Contaminated waste can	1	unit	unknown
	Miscellaneous scrap metal	4		unknown
	Cable	1	unit	unknown
	Breaker	1	unit	unknown
	Iron gates	8	units	unknown
	Scaffolding	2	units	unknown
	Steel	6,500	units	4" - 5" steel
	Nozzles	5,061	units	unknown
	Valves	14	units	unknown
	Gun barrels	25	units	7.6' long, 2" diameter
	Pig tails	2	batch	2 pounds each, about 4,000 in a batch?
	Iron stairs	1	unit	10 feet
	Poison: lead cadmium rods	3,863	pieces	6" long, 1.4" dia., (1 piece=3.36 lbs.)
	"P"	1,900	pieces	Same as poison pieces?

General Material	Specific Material	Amount (number)	Units	Description of Size or Unit Weight
Miscellaneous metal-contd	Spacers (perforated)	208,725	pieces	8" long, 1.4" dia., (1 piece=0.5 lbs.)
	Perf (aluminum)	87,475	pieces	6"-8" pieces (1 bucket=110 pieces)
	Solid aluminum (SA)	67,737	pieces	1 piece=1.4 lbs (1 bucket=110 pieces)
	Weighing tray (lead)	2	units	unknown
	Plate (steel)	6	units	unknown
	Mattress plates	15	units	unknown
	Lead brick	20,441	units	6" pieces, 25 pounds
	Stringer	6	units	2 are graphite
Miscellaneous	Tongs	4	pairs	unknown
	Basin scraps	4	buckets?	unknown
	Viewer	1	unit	unknown
	Ropes and hoses	10	units	unknown
	Conduit	1	unit	unknown
	Table	1	unit	unknown
	Concrete block	1	unit	unknown
	Pinch bar	1	unit	unknown
	Tube box	1	unit	unknown
	Buckets	8	units	unknown
	Chute boxes	1	batch	unknown
	Dirt	18	loads	unknown
	Tube sections	24	buckets	unknown
	Dummie train	3	times mentioned	Westinghouse
	Ruptured slug cans	5	units	unknown
	Segmental discharge equipment	3	times mentioned	unknown
	Flooring	60	feet	
	Shaper	3	units	

thimble was typically made of aluminum and was about 35-feet long with a 3.5-inch diameter and weighed approximately 90 pounds.

- Vertical safety rods were used to shut down a reactor and hold it at sub critical. They are approximately 40 to 50 feet long.
- Process tubes were 40-foot long aluminum pipes with an inside diameter of 1.75 inches and a wall thickness of 0.125 inches and weighed 19 pounds. When expelled from the reactor they were chopped up into 3 to 5-foot lengths with a guillotine. There are about 2,004 process tubes in a reactor.
- Gun barrels are 2-inch pipes that are about 7.6-feet long. They go on the inlet and outlet of the process tube.
- Pigtail is a small pipe with a loop in it that looks like a pigtail. It is a connector between the cross header and the nozzle of the process tube that is used for moving cooling water. A nozzle and a pigtail were mounted on the front and rear of each process tube. A pigtail is estimated to weigh 2 pounds and the nozzle is estimated to weigh 10 pounds.
- Rupture cans are sealed cans containing fuel that had ruptured in the reactor.

3.1.3.2.3 General Overview of 100 and 300 Area Burial Grounds. The detailed listing of items shown in Table 4 is generally comparable with findings from the *Estimates of Solid Waste Buried in 100 Waste Burial Grounds* (WHC 1987), and should be characteristic of the entire burial grounds in general. One exception to the comparison is the under representation of soft waste in Table 4. This under representation is an indication that the current burial ground characterization is questionable and further studies should be conducted to establish a more complete and accurate burial ground characterization.

Table 4 identifies several items expected to be encountered throughout the burial grounds. Additional items that are not listed in Table 4 but may be encountered are industrial equipment, railroad ties, oxygen & acetylene tanks, broken concrete (up to 30 inches in size), pumps, ammunition boxes, graphite, and any items normally found in a landfill.

3.1.3.3 Soil. Soil types in the 100 Area and 300 Area were evaluated to determine types of materials present, range in size of materials, and approximate quantities of the larger sizes.

3.1.3.3.1 100 Area. Surficial deposits ranging from 0 to 10 feet in depth of aeolian material are underlain by the Hanford Formation in the 100 Area. Typical Hanford Formation soils consist of sandy gravels. The Hanford Formation is very non uniform with localities of cobble to boulder sized particles and localities of fine sized particles. The cobbles and boulders tend to concentrate near the river and the finer sized particles tend to concentrate away from the river (Linberg 1993). The cobble and boulder sized material is expected to vary from 18 to 32 percent of the material encountered in the 100 Area with the typical soil containing 18 percent (WHC 1990).

3.1.3.3.2 300 Area. Based on borehole logs from the report *Summary of Drilling and Test Pit Activities For The 300-FF-1 Operable Unit Phase I Soil Sampling Investigation* (WHC 1992), this area is expected to generally contain sandy gravel. Similar to the 100 Area, 18 to 32 percent of this material is expected to contain cobble and boulder sized particles (WHC 1990).

3.1.3.4 Summary. During the first four years of operation, 86 percent of the material reaching the ERDF is expected to consist of contaminated soils. The soils are expected to generally

consist of sandy gravel. Conventional conveyor equipment should be adequate for handling the majority of this material without special processing. It is anticipated that average soils will contain 18 to 32 percent (WHC 1990) material with particle sizes exceeding 6 inches, with the typical soil containing 18 percent. The percentage of this material expected to be encountered will be based on the locations of the remediated areas.

The other materials will be debris from the burial grounds and D&D. Most of the debris may require special preparation to avoid damage, to reduce wear of the transport system, and to improve the physical property of the waste material (such as reduce settlement, reduce leachate formation, and reduce gas generation). These waste proportions are expected to be typical of the entire 22 years of operation of the ERDF.

Based on the burial ground information in the report *Estimates of Solid Waste Buried in 100 Area Burial Grounds* (WHC 1987), the following approximations by weight were made. Approximately 41 percent of the 105 B burial ground debris consists of decomposable material (buried waste) which could be shredded and mixed with soil to improve its properties (such as reduced gas and leachate generation). Approximately 54 percent of the debris consists of metal material that may be a problem for system wear. These values are generally representative of the waste materials in other 100 Area burial grounds (Winship 1993).

3.1.4 Waste Processing

3.1.4.1 Introduction. The purpose of waste processing is to improve the efficiency of waste disposal operations and minimize wear and damage to the transportation system (Gibson 1993). Additionally, some of the processing systems produce a more homogeneous waste form which will reduce settlement, gas generation, and leachate formation. The principal concern for this study is waste processing to achieve size reduction and component separation, but the secondary benefits associated with producing a more homogenous waste will be discussed and recommended for consideration if economically feasible. All equipment prices indicated are based upon production rates of 600 to 700 cubic yards per hour (yd³/hr). The conveyor system is sized for 1,000 yd³/hr. The major types of waste processing equipment commonly used in the waste management industry are discussed in the following paragraphs.

3.1.4.2 Hammer Mills. The hammer mill is designed to break, tear, cut, and crush all types of wastes. The hammer mill is the most commonly used equipment for reducing size and homogenizing the composition of wastes. It is an impact device in which a number of hammers are fastened flexibly to a shaft or disk that is rotated at a high speed. The hammers extend radially by centrifugal force from the center shaft. Wastes enter the mill and are subsequently pounded by a sufficient force for crushing or tearing. Wastes are further reduced in size by being struck against breaker plates and/or cutting bars fixed around the periphery of the inner chamber. The cutting and striking action continues until the material is of the size required. The mills can be provided in sizes able to accept objects which are up to 48 inches in diameter and which will size reduce to 6 inches in diameter.

Approximate costs for the equipment only associated with this system (Williams 1993) are summarized below:

Infeed Conveyor	\$700,000
Mill	852,000
Mill Drive Motor	156,000
Dust-Collection System	<u>175,000</u>
Approximate Total	\$1,883,000

In addition, there will be installation costs (approximately 40 percent of the equipment cost) and building costs.

Other considerations include significant maintenance requirements for the hammer mill and potential delays in processing of waste material. In addition, the maintenance may expose support personnel to hazardous and radiological wastes in confined areas.

3.1.4.3 Crushers. Crushing equipment is varied and the selection of a specific crusher is largely done on the basis of experience and testing. The mechanical reduction of materials by crushers is generally a result of impact (see hammer mill), attrition, shearing, or compression. Attrition refers to a reduction of material by scrubbing it between two hard surfaces. This method of crushing is practical for less abrasive materials such as pure limestone and coal. Shearing consists of a trimming or cleaving action. Shearing is usually combined with other methods for best results. Shearing is generally used for friable material. Compression is done between two surfaces, with the work being done by one or both surfaces. Jaw crushers using this method of compression are suitable for reducing extremely hard or abrasive rock. Some jaw crushers employ attrition as well as compression and are not suitable for abrasive rock since the rubbing action accentuates the wear on crushing surfaces. As a mechanical reduction method, compression should be confined to hard, abrasive, non-sticky material. Consequently, 82 percent of the waste material from the burial grounds will be suitable for processing by a crusher. Crusher costs are similar to the hammer mill costs.

3.1.4.4 Air Classifiers. Air classification provides separation of various components from a dry mixture. Generally, air classification is used to separate the organic material (light fraction) from the heavier inorganic material. Its potential use for processing the incoming waste materials at the ERDF will be to separate the heavier, hard materials for processing by a hammer mill or crusher from the lighter materials which could be processed by a shredder.

The principal components of a complete air classification system are the air classifier, one or more conveyors for transport of processed wastes to a loading hopper, and a cyclone separator to separate the light fraction from the conveying air. Before discharge to the atmosphere, the conveying air is passed through a dust collection facility. Air for the operation is supplied by low-pressure blowers or fans.

The use of air classification must be based on material characteristics, feeding systems from shredder to air classifier, air flow constraints, routine and specialized maintenance requirements, pollution control requirements, and environmental limitations. The air classification system is labor and mechanical intensive. In addition, dust control of hazardous laden material will require constant monitoring. Because of these concerns and the small quantity of organic material indicated to be present in the burial grounds (estimated to comprise 41 percent of the solid waste), this process system is not considered further.

3.1.4.5 Shredders. Shredders can process light and medium wastes into a uniform waste material consisting of small particles. This uniform waste is desirable for the ERDF because of its ease of handling and because of the uniform blending of decomposable material with inorganic material. This blending will result in reduced potential for differential settlement, gas generation, and leachate production.

The shredder design is sometimes based on the hammer mill principle of operation in which rotating rows of hammers shred the material against rows of special steel bars or grates. The width of the hammer is narrow, enabling it to rip and tear the wastes while grinding it against the screen bars.

Shredders have been used to handle all types of municipal wastes. However, application for the ERDF may be limited due to the prevalence of metal objects in wastes from the burial ground (which may comprise 59 percent of the debris from the burial grounds) which, unless removed by air classifiers or magnetic systems, will result in significant damage to the shredder and make frequent maintenance necessary. Approximate costs associated with the equipment only for this system (Williams 1993) are summarized below:

Infeed Conveyor	\$310,000
Shredder and hopper	330,000
Mill-Drive Motor	117,000
Dust-Collection System	<u>175,000</u>
Approximate Total	\$932,000

In addition, there will be installation costs (approximately 40 percent of the equipment cost) and building costs.

3.1.4.6 Magnets. A substantial portion of the wastes from the burial grounds (approximately 54 percent) consists of metals that could cause some accelerated wear of the conveyance system considered in this study as well as problems with many of the waste processing systems considered in this section. These metals include ferrous metals, aluminum, and lead. The most common method of recovering ferrous scrap from shredded wastes involves the use of magnetic recovery. Magnets do not remove aluminum or lead.

The location of magnets with respect to the processing operation is dependent on a specified purity requirements for handling. The most common designs of magnetic separation are the suspended magnet, the magnetic pulley, and the suspended magnetic drum. All of the aforementioned magnet arrangements involve a conveyor. The conveyor delivers materials in close proximity to the magnets. A two magnetic drum installation at the end of the conveyor may provide a relatively metal free waste. The first magnet drum tosses ferrous material to an intermediate conveyor. The second drum is positioned at the end of the intermediate conveyor for a final separation process.

Factors to consider in the selection of magnetic separation equipment are location of ferrous material, characteristics of the waste, waste tendency to clump or stick, size (all material should be reduced in size to about 8-inch or smaller), and moisture content. Consequently, significant preprocessing of the waste material (such as size reduction by a hammer mill) is required prior to the metal separation process. Approximate costs associated with the equipment only of a self-cleaning magnet system (Waha 1993) and conveyor (Hynek 1993) are summarized below:

Infeed Conveyor	\$33,000
Magnet and cleaning belt	20,000
Miscellaneous Equipment	<u>8,000</u>
Approximate Total	\$61,000

In addition, there will be installation costs (approximately 40 percent of the equipment cost) and building costs.

3.1.4.7 Size Separation (Grizzly). The "grizzly" consists of an inclined grid and the maximum size desired is set as the spacing between the bars (in this case 6 inches). The grid is vibrated to facilitate the movement of material through the grids or off the face of the grid into a collection container. The bars forming the grid can be damaged by boulders or blocks of concrete that are larger than 3 feet in diameter and fall from heights greater than approximately 5 feet.

A "grizzly" separates the oversized material from the waste as it arrives at the ERDF and provides a low cost means of controlling the size of the waste material carried on the conveyor system. This waste processing system will require an alternate means of transporting the oversized material to the disposal trench because the "grizzly" does not reduce the size of the objects comprising the waste and this over-sized waste can not be transported by the conveyor system. The alternative transportation system will be required in any case to transport the occasional single-use container so there is little additional capital cost above that of the "grizzly" itself. Approximate costs associated with the equipment only of this system (Hill 1993) are summarized below:

Grizzly and Motor	\$58,000
Dust Enclosure	<u>22,700</u>
Approximate Total	\$81,300

In addition, there will be installation costs (approximately 40 percent of the equipment cost) and building costs.

3.1.4.8 Super Compactors. Super compactors have been used in private industry and at several DOE facilities (Rivera et al. 1989) and (Bohrer et al. 1987) to densify waste materials and reduce the amount of landfill space required for disposal. The super compactor is a hydraulic press with the largest systems applying up to 2,200 tons of force on containers filled with waste and handling up to 40 containers per hour. Densification of several different waste types, such as scrap metal, small electric motors, and concrete paving blocks increased the density from 49 to 207 lbs/ft³, 60.5 to 230 lbs/ft³ and 50 to 81 lbs/ft³, respectively. The container is held in a mold during the compaction process to avoid damaging the container and ventilation systems are connected to hepa filters in situations where radioactive dust may be generated (Williams 1992).

Super compactors range in capital cost from \$1.5 to \$5 million and operating costs vary from \$20 to \$35 per container. In addition, a building is required for housing the equipment. Approximate costs for a super compactor are summarized below (Williams 1992):

Equipment Capital Cost	\$2,000,000
Building Cost	<u>750,000</u>
Approximate Total	\$2,750,000
Operating Cost per Year	\$1,260,000

The cost of the super compactor does not appear warranted given the relatively low anticipated costs of disposal space at the ERDF and the fact that improvements in waste stability can be easily accomplished by a grout facility that is being provided as part of the project. Consequently, super compactors are not considered further.

3.1.4.9 Vibratory Screens. Vibratory screens use a grid screen to separate soil materials into specific sizes. These screens are shaken or vibrated to facilitate the soils movement through the grids in the screen. Because the agglomerator is not able to accept sizes larger than 1-inch in diameter and because the agglomeration process works best on material smaller than 10 mm in size, it will be necessary to remove the larger material using a single stage vibratory screen and route the larger material around the agglomerator by conveyor. After the finer material has passed through the agglomerator, the larger material could discharge onto the conveyor carrying the finer material so that the larger material caps the finer material. The vibratory screen will be damaged by large cobbles or boulders and it will be necessary to pretreat the waste stream to remove this material using a "grizzly" or reduce that material to a size smaller than 6 inches using equipment such as a hammer mill. Approximate costs for vibratory screen equipment only

which will separate the sizes larger than 10 mm in diameter (but less than 6 inches) are shown below (based upon approximately 20 percent of the waste soil material having sizes between 1 inch and 6 inches (WHC 1990):

Grizzly Screen and Hoppers	\$100,000
Feeders and Conveyers	600,000
Vibratory Screens	<u>240,000</u>
Approximate Total	\$940,000

In addition, there will be installation costs (approximately 40 percent of the equipment cost) and building costs.

3.1.5 Recommended Waste Acceptance Criteria

Waste acceptance criteria based upon minimizing the wear and damage to the conveyor transportation system and the waste-processing equipment that facilitates the conveyor operation are listed below:

- The primary waste material that the ERDF will handle will be soils and overburden material which will be easily accommodated by all components of the conveyor system.
- Soil material shall be less than 3 feet in diameter (to avoid damage to the "grizzly" and containers)
- Non-overburden and non-soil wastes from the burial grounds will not be transported by conveyor. The majority (59 percent) is larger than 6 inches and it will be a more streamlined operation to transport all burial ground waste by alternate means rather than process all the burial ground waste through the "grizzly" to collect a relatively small percentage of material that can be transported by conveyor. This will require source separation at the remediation sites.
- Processing of organic material from the burial grounds to produce a uniform material blended with inorganic material will require an extensive processing system consisting of either air classifiers or magnets in addition to the shredder. The heavy maintenance requirements of such an elaborate system along with its high capital costs is not warranted for the relatively small quantity of organic material which is anticipated (41 percent of burial ground waste).
- Removing metallic objects from the wastes will provide some reduction in wear of the system, but this benefit is not significant enough to warrant the high costs of preprocessing the material by either milling or crushing in addition to the costs of the magnet.
- Oversized objects from the burial ground and cobbles and boulders contained in soil materials comprise a significant proportion of the wastes (82 percent of burial ground wastes and 18 percent of soils) and must either be reduced to less than 6 inches in diameter so that it can be transported by the conveyor system or be separated from the other waste material and transported by truck into the trench. The size reduction (by hammer mill) will have high capital and operation costs compared to the simple and inexpensive process of separating out the oversized by use of a "grizzly."

- The material larger than 10 mm in diameter must be size reduced or separated from the material that will pass through the agglomerator. Removal of the material larger than 10 mm in size by use of the vibratory screen is recommended rather than size reduction using a hammer mill because of the significant difference in costs and complexity of the two systems.
- Based upon the types of waste anticipated to be received by the ERDF and their associated quantities, the recommended processing system consists of using a "grizzly" to separate out objects in the waste material larger than 6 inches and a vibratory screen to remove objects larger than 10 mm in size. The material which is between 10 mm and 6 inches in size will be routed around the agglomerator and used to cap the finer material on the conveyor.

3.2 CONTAINER TYPES

3.2.1 Introduction

The present plan for shipment of wastes from the remediation sites to the ERDF loading/off-loading facility consists of transporting the wastes in containers loaded on rail flat cars. The scope of this study includes reviewing alternative systems for transporting the wastes to the ERDF to determine if these systems may have economic advantages and be more suited to the area fill method of disposal. The scope of this study is qualitative and if further consideration of these alternatives appears warranted, then a more detailed study will be required.

Several types of railroad cars were reviewed including the rapid discharge hopper car, the rotating coupler car, the hopper car, the ballast or side dump car, and the container adapted flat bed car. In addition, using sacks and liners to minimize both the release of fugitive dusts and the need for decontamination were included in this study.

3.2.2 Alternative Rail Car Transportation

3.2.2.1 Rapid Discharge Hopper Car. The rapid discharge hopper car is currently used by the private industry primarily for coal transport. It has a capacity of approximately 140 yd³. The dump action is a rapid discharge design and can be completed in approximately 30 seconds. Discharge bottom sealing can be a problem and spillage can occur. A trestle with receiving hopper will be required for waste discharge at the site if this conveyance is used. During discharge, the rail car could become contaminated with spillage or dust and the rail car will require decontamination.

3.2.2.2 Rotating Coupler Car. A rotating coupler car is used for coal and waste transport. It has a capacity of approximately 140 yd³. The dump action results from a 180 degree rotation of the car above a hopper with grizzly. The rotating equipment is expensive (may cost up to \$1 million) and should be considered permanently mounted. The cars may require cross member support of side walls. The cross members can be damaged by improper loading techniques or oversized waste. This type of operation is currently used for unloading waste material at the Envirocare facility in Utah. During discharge, the rail car could become contaminated with spillage or dust and the rail car will require decontamination.

3.2.2.3 Hopper Car. The hopper car is also used by private industry for coal transport. It has a capacity of approximately 134 yd³. The dump action is either by bottom outlet, rotary dump or

both depending on the car series. Bottom discharge can take approximately 10 minutes because the doors must be manually opened. Rotary dumping discharge occurs in approximately 3 minutes. A trestle with receiving hopper will be required for bottom discharge if employed at the ERDF. During discharge, the rail car could become contaminated with spillage or dust and the rail car will require decontamination.

3.2.2.4 Ballast/Side Dump Car. The ballast/side dump car is currently used by several railroad companies to carry rip-rap to washout areas. It has a capacity of approximately 140 yd³. It takes approximately 3 minutes to dump this type of car. The dump action results when a hydraulic ram is activated. A receiving hopper will be required at the site. During discharge, the rail car could become contaminated with spillage or dust and the rail car will require decontamination. Typical cost for each side dump car is approximately \$750,000.

3.2.2.5 Container Adapted Flat Bed Car. The container adapted flat bed car is similar to the cars currently used at the Uranium Mine Tailings Reclamation Act (UMTRA) operation in Grand Junction, Colorado. Two removable containers are placed on each rail car. In one option, at the ERDF, the containers are individually removed and dumped. If placed on a truck to be hauled to the trench, it is the "Waste Materials Transportation by Truck" alternative (See Section 5.1). If dumped into a hopper for conveyor transportation to the trench, it is the "Waste Materials Transportation by Conveyor" alternative (see Section 3.3). In another option, the container would be locked to the rail car and the entire car tipped (rotated) for unloading (see Section 3.3.2). In this last option, the rail car could become contaminated with spillage and the rail car will require decontamination.

3.2.2.6 Evaluation of Alternative Rail Car Transportation. The alternative rail car systems, in general, provide quick and convenient emptying of the car. The key issue in deciding whether these alternatives are more desirable than the present plan which uses containers (see Section 5.1) is the length of time and cost for decontamination of these alternative rail car systems. The decontamination effort required for rail cars similar to the alternative ones listed in this study was determined based upon experience at existing waste disposal and mining facilities and is described in Section 4.1, Decontamination. As indicated in Section 4.1, the decontamination costs and time required are anticipated to be significantly more than for a transportation system based upon containers. Consequently, further study of alternative rail car transportation systems is not warranted.

3.2.3 Liners and Sacks

3.2.3.1 Introduction. Liner and sack usage in containers is being considered as a means of preventing fugitive dust emissions during emptying of the containers and the resulting contamination of the container and adjacent areas. This portion of the study will determine the approximate costs of the liners and sacks and compare these costs with the cost of decontamination that their use may eliminate.

3.2.3.2 Liners. Some liners include several impermeable plies and are reinforced with a high strength grid to provide a waterproof and tear resistant material. Liners are currently available in sizes up to 22 by 7.5 by 10 feet. Filled liners are cumbersome to move and relocation after dumping into a disposal trench may be difficult. Bulky, sharp objects may tear the liner during unloading and relocation. Thus, waste processing may be required to remove these objects from the waste prior to filling the liner. Use of the liners will allow full load transport of the container without use of a dust abatement cover, will eliminate or minimize the need to decontaminate the rail car or container and will reduce fugitive dust emissions which may be a concern for worker safety. Typical costs for a liner with a size of 22 by 7.5 by 10 feet (32 yd³) is \$118.40 per liner

(Scarborough 1993). If 28.5 million yd^3 of waste material were to be placed into liners and each liner held 32 yd^3 , then approximately 890,100 liners will be required. At a cost of \$118.40 each, the total cost for liners will be approximately \$105 million. Despite the qualitative nature of this evaluation, it is obvious that the cost of the liners will never be compensated for by the cost of decontamination which is estimated to have capital costs of \$5.3 million and annual operation costs of \$487,920 (COE 1993d).

3.2.3.3 Sacks. Sacks are engineered to accommodate dry or semi-moist flowable materials in capacities to 80 cubic feet (ft^3) or 4,400 pounds. The sacks are made of durable woven polypropylene fabric material with polyester lifting straps for fork lifts (for easily loading onto trucks or rail cars). Filling, loading, and off-loading can be time consuming and could delay disposal efforts. In addition, use will require an intensive labor and equipment effort. A typical cost for a sack that contains 28 ft^3 (approximately 1 yd^3) of waste is \$14.50 each (Clancy 1993). If 28.5 million yd^3 of waste were to be placed into sacks and each sack held 1 yd^3 , then 28.5 million sacks would be required. At a cost of \$14.50 per sack, the total cost for the sacks will be approximately \$413 million. The cost of the sacks could not be compensated for by elimination of the decontamination facility.

3.2.4 Evaluation and Summary

Alternative rail car systems will require special unloading facilities which are substantially more expensive than the current plan for transportation of waste using containers and unloading using simple fork lift systems. Additionally, these rail cars will require additional time and expense to decontaminate. Using liners and sacks is not cost effective. Based upon these considerations, the current plan of using removable containers on flat bed rail cars appears to be the best suited for transportation to the ERDF.

3.3 MECHANICAL CONVEYING COMPONENTS

3.3.1 Conceptual Design Criteria

The mechanical conveying system comprises a receiving building, a screening and agglomeration facility, and transportation and fill placement conveyors. Figure 3 is a conceptual general arrangement of the system. Figure 4 is the process flow diagram of the system. The design is based on the criteria discussed below.

3.3.1.1 Material To Be Conveyed. Up to 2 million yd^3/year of CH-LLW, predominantly comprised of excavated overburden and soils with some buried, demolition, or decommission wastes. CH-LLW overburden and soils are anticipated to comprise 84 percent of the total waste volume (see Table 3-1.) It is expected that most of the buried waste and demolition and decommission wastes will be source separated prior to transportation to the ERDF. The CH-LLW and non-hazardous metals, buried wastes, demolition, and decommission wastes (12.5 percent of the total waste volume), RH-LLW (0.5 percent of the total waste volume), CH-Mixed LLW (1.8 percent of the total waste volume), RH-Mixed LLW (0.5 percent of the total waste volume), and Hazardous/Dangerous wastes (0.7 percent of the total waste volume) will be handled separately (see Section 3.3.8).

The material designated for conveyor handling (CH-LLW overburden and soils) will be mostly 6 inch and smaller with approximately 50 percent by weight being 10 mm (0.375 inch)

Figure 3. Site Plan.

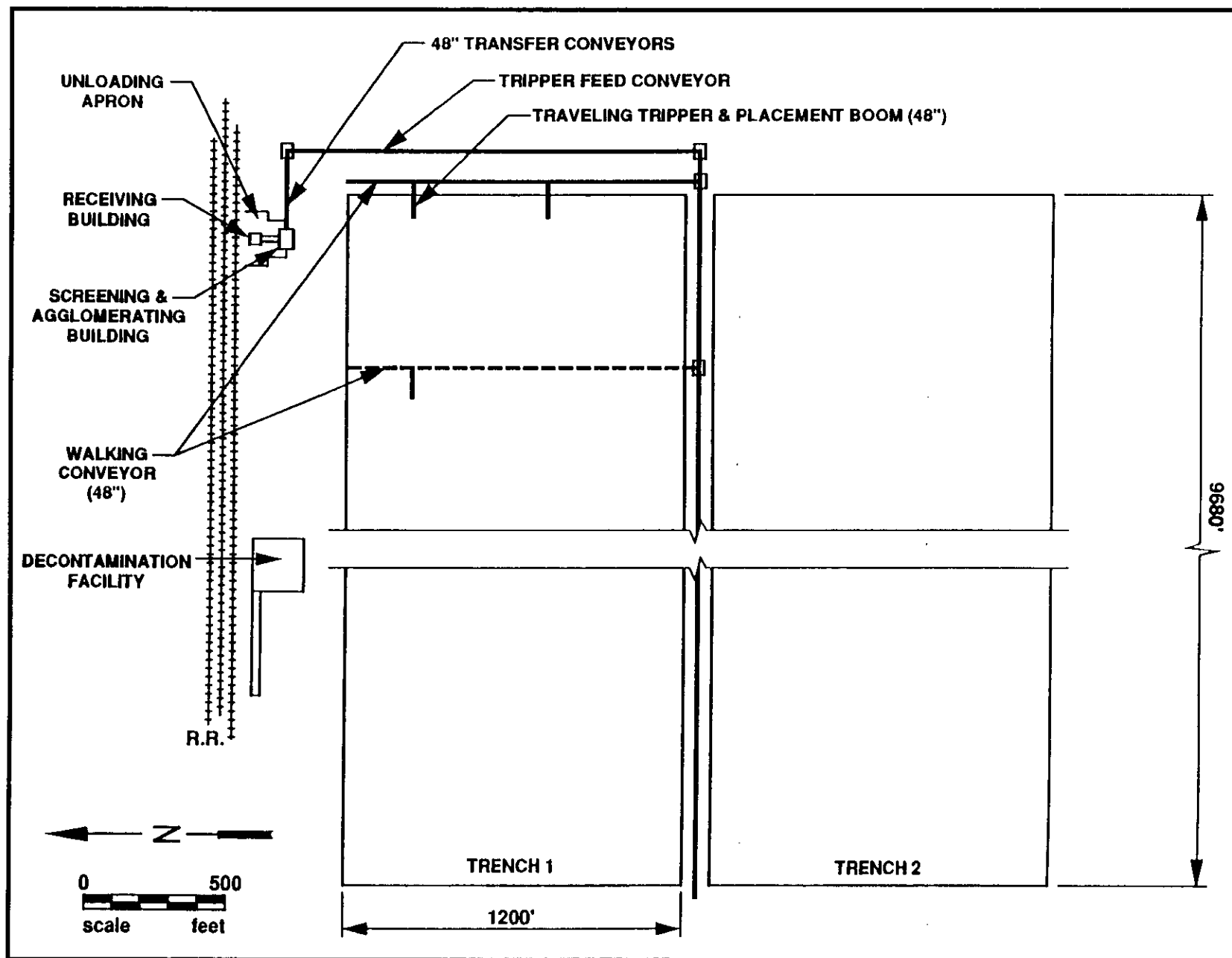
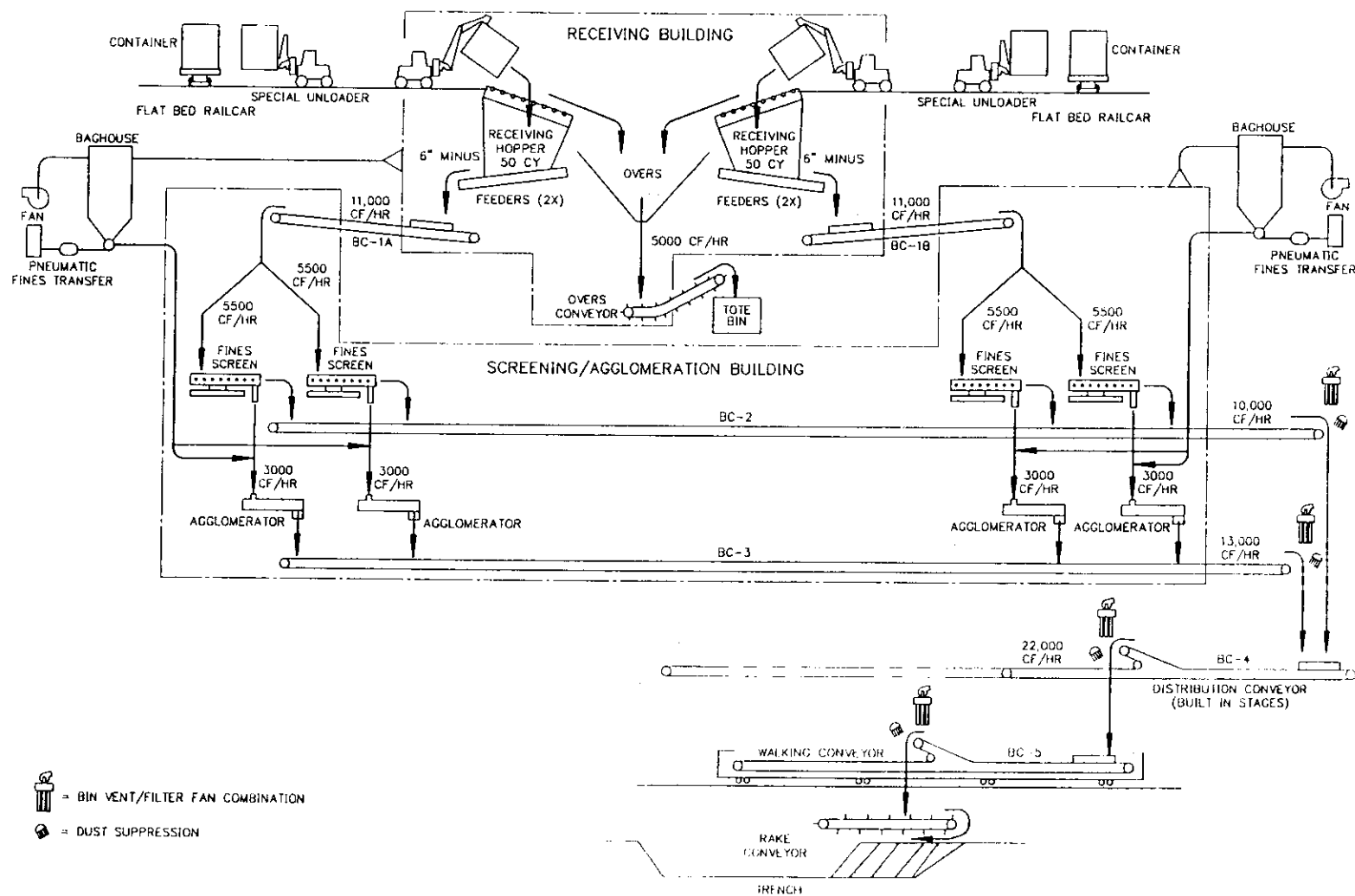


Figure 4. Process Flow Diagram Conveyor Transportation.



and smaller. The CH-LLW overburden and soils will be delivered to the ERDF in 35-yd³ capacity (32 yd³ net), 8-ft x 8-ft x 15-ft containers and is expected to consist of cobbles and gravelly soils with an average loose density of 100 lb/ft³. About 18 percent of the overburden and soils will be too large for the conveyor system (6 inch maximum). During certain periods of remediation site work, all the waste will be overburden and soils so the conveyor system is sized accordingly. During other periods of remediation site work, all or the vast majority of the waste materials will be unsuitable for conveyor transportation so truck transportation will be required. It is assumed that this waste will be received over a 4 month period each year.

3.3.1.2 Waste Receiving Trenches. Trenches will be constructed in pairs to facilitate conveyor operation. Each trench will be 1,000-feet wide at its base, 33-feet deep and have side slopes constructed on a 3 horizontal to 1 vertical grade (3H:1V), (see Section 6 for explanation of trench geometry).

3.3.1.3 Operational Period and Flows. Twenty two years operational project life. A peak annual flow of approximately 2 million yd³ of waste material will be delivered to the ERDF over a period of 250 operating days per year. Half the year the facility will operate one 8-hour shift per day. Two shifts will operate the remaining half year during long daylight days. This will result in a system average handling rate of 670 yd³/hr. Allowing for container arrival delays and equipment downtime, the equipment design rate was increased 50 percent to 1,000 yd³/hr.

3.3.2 Rail Car Versus Container Dumping

Flat bed rail cars will be used for delivering the containers to the ERDF site (see Section 3.2.2). Two options were considered for unloading the containers. One option will lock the container to the rail car and unload by tipping the combination. The other option will be to lift the container off the car before tipping. The latter option was selected as it provides an economical means of handling surges in the delivery of containers to the ERDF and flexibility in scheduling the conveyor system operations and handling system interruptions. Also, the former option would contaminate the rail car which would require extensive decontamination.

Wheeled container loaders will be used to remove the containers from the rail cars and transport them to receiving hoppers. The wheeled container loaders will be fitted with articulated forks which will tip the container to unload its contents. The containers could be designed for either open top discharge or discharge through end doors. If open top discharge is used, the container will be fitted with a removable lid. After discharge the containers will be returned and set back on the rail cars by the wheeled container loader. There is a potential for the exterior of the container to become contaminated during dumping then this contamination pass to the rail car. The rail car would then be moved, the container removed by another wheeled container loader and the container decontaminated in the decontamination facility. It would then be placed onto the rail car for transportation back to the remediation site.

An advantage of using wheeled container loaders to unload the container is that the number of rail cars and amount of rail storage track can be less than if the containers remain attached to the rail car for dumping. When containers are received more quickly than the conveyor system can handle, the containers will be set down in a temporary holding area. This will allow the rail cars to return without delay to the remediation sites. The containers held in the loading area could then be emptied to suit the availability of equipment at the ERDF. Avoiding delay in return of the rail cars will result in the use of the least numbers of rail cars which will result in a cost saving.

3.3.3 Conveyor Start Point and Receiving Facility

Conveyor starting points at Suzie Switch, approximately 6 miles north of the ERDF, and at some intermediate point were considered. Belt conveyor construction costs are about six times more expensive than railroad track costs. Spillage of low level radioactive waste from the conveyor belt could contaminate the surrounding area. Using the shortest length belt conveyor will reduce the possibility of contamination. The hazard of contamination plus the extra cost of the conveyor belt makes it most appropriate to haul the material by railroad as close as possible to the disposal site. Thus the north end of the ERDF was decided as the most suitable location for the container receiving facility.

The receiving building will include a paved apron, container storage area, and a building to enclose the dump hoppers (see Figure 5). It is expected that 1 wheeled container loader will be able to pick a loaded container from the rail car, dump its contents, and return the empty container to the rail car in 4 minutes. The rate is based on the assumption that the rail cars are positioned, either by a car hauler or locomotive, within a couple of hundred feet of the receiving building. Two wheeled container loaders will be required to unload 1,000 yd³ of waste (31 containers) in an hour. It is suggested that a third wheeled container loader be provided to assure equipment availability during maintenance overhauls and equipment breakdowns. If top discharge containers are used, the rail car unloading track will also have an overhead gantry crane to remove and reset the container lids. The building will be ventilated through air filters but not through hepa filters. It is very difficult for hepa filters to handle this volume of dirty air. Also, since this option uses the same dumping of containers as the truck transport option and the truck transport option does not have hepa filters, hepa filters were not included.

Two dump hoppers will be situated inside a dust containment enclosure. The hoppers will be sized to provide, together with material on the transportation belts, 15 minutes of surge storage. This surge storage will permit the conveyor system to run at a uniform capacity during brief periodic breaks by the wheeled container loader operators.

Each hopper will be equipped with a grizzly to prevent objects larger than 6 inches from being conveyed through the system. The oversize objects will drop on to a conveyor belt which will deposit the material in a tote bin. Material, 6 inch and smaller, will be fed from the hoppers by vibrating feeders to the screening area infeed conveyor belt. Oversize materials collected in the tote bin will be taken by truck to the disposal trench.

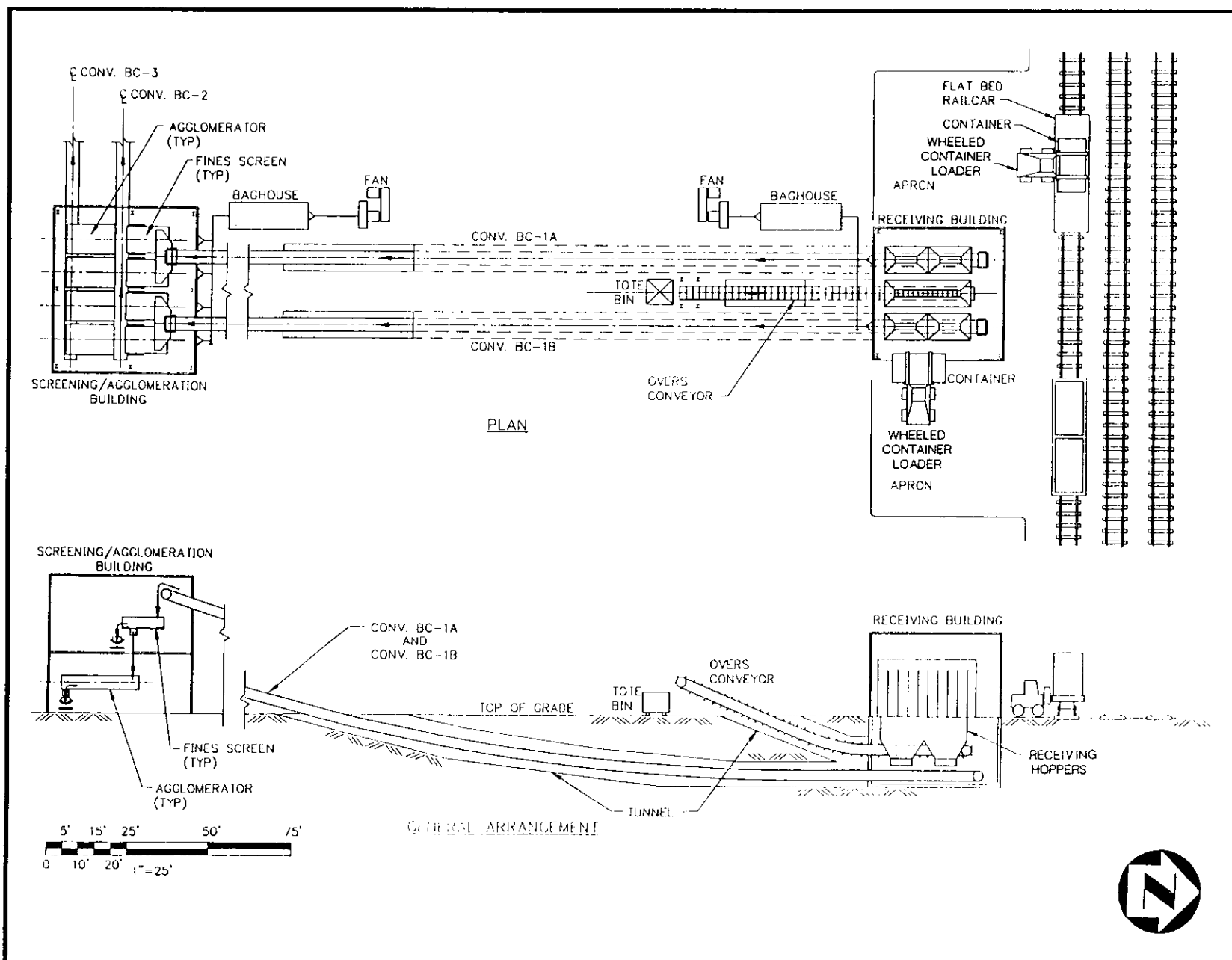
As mentioned previously, the receiving building will be enclosed for dust containment and, as discussed in Section 3.3.6, will have a bag house type ventilation system. Surfactant sprays will also be added in the hopper to control dust emissions.

3.3.4 Screening/Agglomeration Area

The screening/agglomeration area, illustrated in Figure 5, will consist of a building to house the processing equipment. Agglomeration of fine materials will be used as part of the dust control features of the ERDF. Material arriving from the hopper conveyor will be split into 4 flows. Each flow will pass through a screen to separate fines and coarse materials. Vibratory style screens will be used.

Separating and not treating the coarse material, which is basically pebble size and larger and is not prone to dusting, will improve the efficiency of the agglomeration process and result in better dust control. The fine material (less than 10 mm) will be sent through a paddle mixer where a liquid will be sprayed into the mixer to agglomerate the particles. Coarse material will

Figure 5. Screening/Agglomeration Area.



by-pass the agglomeration units and be merged with the agglomerator discharge material for transportation to the disposal trench.

Separating the material into 4 flows allows use of economically sized screening and agglomeration units and also provides redundancy for equipment maintenance and breakdowns. The redundancy will allow system flow to continue without severe reduction during equipment maintenance shutdowns or in the event of an equipment failure or flow blockage.

As discussed in Section 3.3.6, the building will be ventilated by a bag house style air filtering system. Transfer chutes will also have air pickups which will discharge to the bag house.

3.3.5 Distribution and Placement Conveyors

Waste material will be transported from the preparation area to the ERDF disposal trenches by a belt conveyor. At the disposal trench, the material will be transferred to a distribution conveyor. The distribution conveyor will be equipped with a traveling tripper that will feed the material to a walking conveyor. The walking conveyor will be equipped with a stacking boom to transfer the material to a placement machine for final deposition in the trench. The purpose of the placement machine will be to deposit the materials in controlled layers that will be readily compacted and to minimize the drop height to limit dust generation.

The belts on the transportation and placement conveyors will be 48 inches wide. The width was selected to be economical, to be able to meet design capacity at relatively low speed (250 feet per minute), and to maintain an ample (3.5 inch) edge distance for spillage prevention. The conveyor belt cover material will be able to resist damage from sharp or jagged edges of rock and ferrous materials. Impact resistant idlers will be used at all loading points to resist impact from the larger waste material particles.

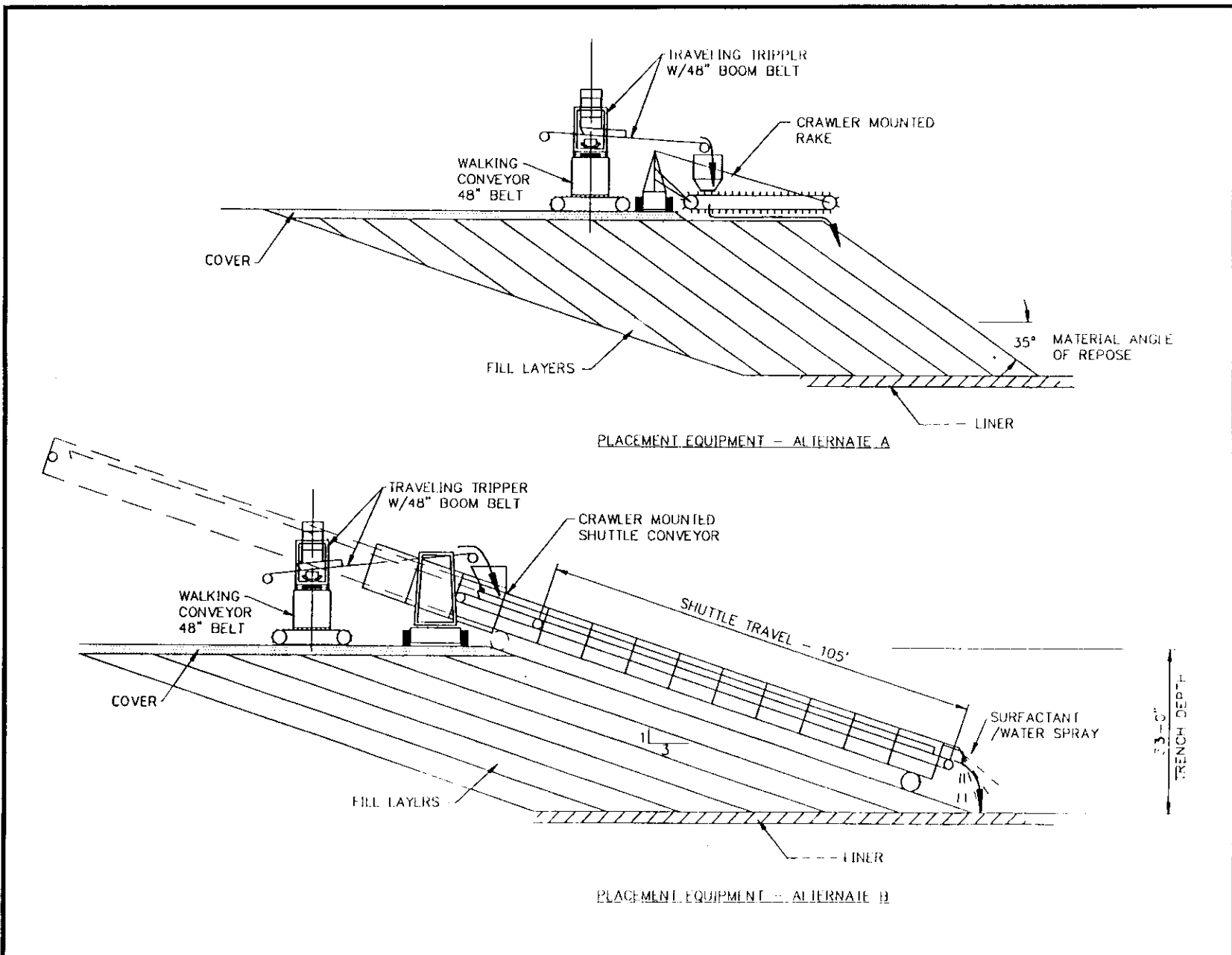
It is estimated that the belt conveyor system, including hopper discharge equipment, screens, agglomerators, conveyor belts, and trippers will have a worst case system availability factor in excess of 80 percent. This will exceed the availability factor of 67 percent required to achieve a 670 yd³/hr average handling rate.

The distribution conveyor will be constructed in several phases over the lifetime of the ERDF project. The phasing will result in reduced power demand during the earlier years of the project life. The walking conveyor can readily move transversely and radially. This will permit the walking conveyor to be alternated from one side of the distribution conveyor to the other as the trench is filled and the distribution conveyor is extended. Extension of the distribution conveyor will require a brief downtime of 2 or 3 days to tie-in an additional drive and splice the conveyor belt.

The walking conveyor, together with a placement machine, will place and spread successive layers of waste material across the width of the disposal trench while advancing along the longitudinal axis of the trench. The equipment will operate from the top of the trench. To advance the walking conveyor across unconsolidated fill, the conveyor will be mounted on crawler tracks. A tripper mounted on the walking conveyor will discharge the material to a fill placement machine. Both machines will be electrically driven.

Two types of placement concepts, as shown in Figure 6, have been considered. Alternate A is based on a rake conveyor. In this configuration, the walking conveyor's tripper will feed to a boom mounted on the tripper assembly. This boom will feed waste material to a separate

Figure 6. Placement Equipment Alternatives.



crawler mounted rake. The rake will push the material out and over the crest of the trench working face.

The Alternate B placement machine is a crawler mounted telescoping boom which will receive material from the walking conveyor's traveling boom. The placement boom will deposit a uniform layer of waste material on to the trench's sloping face from its bottom to top. To facilitate consolidation and settlement of the waste material, a vibrating roller could be placed at the tip of the boom. The roller will work the surface of each previously placed fill layer as the next layer is placed.

It should be noted that other types of fill placement machines may be possible including machines that are integral with, instead of separate of, the walking conveyor. Alternates A and B have been conceived only for the purpose of ascertaining system feasibility. Informal discussions held with suppliers of such equipment has verified the practicality of the concepts.

3.3.6 Dust Control and Clean-Up Features

Several forms of dust control are incorporated in the conceptual design of the belt conveying system. These include:

- Agglomeration of fine material. This process will bind the finer fractions of waste together using a conditioning agent to make the particles too heavy to become airborne.
- Use of dust suppression sprays in areas where the waste material trajectories are unconfined such as at the dump hoppers, loading skirts at open top conveyors, and discharge end of the fill placement conveyor. The dust suppression material will consist of a surface tension reducing compound (i.e., surfactant) diluted with water.
- Use of pulse jet dust collectors to collect fugitive dust at all enclosed transfer points, from the interior of the dump hopper building and from the screening/agglomeration building. Dust collected in the local area of the dust collectors will be piped to the infeed of the agglomerator units. Tote boxes will be utilized at remote conveyor transfer points to hold dust for pick-up by mobile equipment. The tote boxes will be emptied into the agglomeration units.
- Hood covers on all exposed conveyor belts except those, such as on tripper conveyors, which are impractical to cover.
- A minimum number of transfer points and use of small drop heights in areas where the material trajectory cannot be confined in chutes such as at the discharge end of the placement machine.
- Liberal edge distances on all conveyor belts to reduce the chance of spillage.
- Easily removable and replaceable transfer and loading chutes for clean-up and decontamination purposes.

In addition to water for dust suppression, water will be required for periodic wash down of the conveyor system for decontamination. A water supply line will run the full length of the distribution conveyors. A separate line will be attached to and run the length of the walking conveyor. Whenever water is needed the walking conveyor water line will be connected by flexible hose to outlets spaced along the length of the distribution conveyor. Hose spigots for

connection of pressure washers and fire hoses will be installed along the length of the water lines. The water lines will be buried where possible and freeze protected by heat tracing where exposed.

Surfaces beneath the fixed conveyor will be paved and sloped to paved ditches to capture any run off water from the conveyors. Collected water will flow by gravity towards the southern boundary of the site. From there the water will be pumped to the decontamination facility wastewater treatment system.

3.3.7 Simultaneous Transportation of Multiple Materials

The feasibility of using the conveyor system for handling several categories of materials and waste streams was considered.

Transportation of the bentonite trench liner material was considered to be unfeasible because its plasticity and sticky nature makes conveying and placement impractical for handling by the same conveyors required for the waste material. Transportation of the operations layer of the liner might be feasible and could be considered further during conceptual design if the conveyor alternative is selected for implementation. To avoid contamination, it was considered not viable to transport cap material. Consideration was also given to use the conveyors for transportation of trench excavation material. Additional equipment will be required for the conveyors to be utilized in this manner so the feasibility was not explored further.

Judgment indicated that the small volume of other wastes, with their differing handling requirements, will be uneconomical to handle by conveyor system. Therefore, it was decided to design the system as a single commodity conveyor system and only for the CH-LLW overburden and soils which comprises about 86 percent of the waste stream.

3.3.8 Transportation Of Materials Not Within Bounds Of Normal Case

Material which can not be transported via the conveyor system (such as RH-LLW, the oversized soil material, buried wastes, demolition wastes, decommission wastes, CH and RH mixed LLW, and single-use containers) will be transported from the off-loading facility (or from the "grizzly" oversized material tote bin) into the trenches by an alternative transportation system. This alternative transportation system will be similar to the system described in a previous transportation study for conventional disposal trenches (DOE/RL 1993b) (truck haul to trench, multiple-use container transport) and will consist of a wheeled container loader which transfers the containers from the rail cars to trucks for transport into the disposal trench. The same wheeled container loader will be used to transfer the containers to trucks as used to empty the containers at the railhead. Contamination of the trucks will be avoided by dumping the waste in remote portions of the trench (this avoids traveling over waste material that was previously placed).

3.3.9 Summary and Conclusions

A mechanical handling and conveying system will have sufficient capacity to handle 2 million yd³/yr of CH LLW overburden and soils. To ensure proper operation, large material, demolition debris, mixed LLW, and single-use containers should be source separated and routed directly to the trench. The mechanical handling system will screen material larger than 6 inches in size with a "grizzly". This screened material will be placed in a tote bin for hauling to the

trench. Material smaller than 6 inches and larger than 10 mm will be removed by vibrating screens. Material smaller than 10 mm will be agglomerated (for dust control) and combined with the midsized material. The combined waste will be conveyed and placed in the trench. Additional dust control measures will be implemented at the transfer points. The system will operate with minimal staff.

4.0 MISCELLANEOUS COMPONENTS

The purpose of this section is to evaluate whether there are special decontamination costs and considerations associated with the conveyor and the alternative rail transportation systems being considered in Section 3.2.2, Alternative Rail Car Transportation.

Also, the use of material excavated during the construction of the trenches for constructing the trench liner and the Hanford Barrier are presented in Section 4.2. Also in this section, the hauling of excess material to the remediation sites for backfill is discussed.

Finally, the maintenance support issue is presented in Section 4.3.

4.1 DECONTAMINATION

4.1.1 Introduction

The purpose of this section is to evaluate whether there are special decontamination costs and considerations associated with the conveyor and the alternative rail transportation systems being considered in Section 3.2.2, Alternative Rail Car Transportation.

4.1.2 Conveyor Decontamination

Previous radioactive waste remediation projects which have utilized conveyor systems to transport radioactive wastes were investigated to determine the decontamination problems and requirements for conveyor systems. Decontamination did not present any serious concerns at other projects and a simple washing of the conveyor with a hose at regular intervals (3 to 5 days) was all that was required (Moroney 1993). A similar type of operation is recommended for any conveyor system used at the ERDF.

4.1.3 Rail Car Decontamination

4.1.3.1 Decontamination Experience at T Plant. Decontamination of rail cars at Hanford's T Plant has historically required 4 hours. However, not every rail car will pass on the first survey so multiple decontamination episodes are required. Currently hand wands that use excessive amounts of water (no recycling) are in use.

4.1.3.2 Decontamination Experience at Envirocare of Utah, Inc. The Envirocare facility at Clive, Utah handles several rail cars per year which contain bulk waste materials and which require decontamination (Peterson 1993b). The rail cars are inspected prior to off-loading or dumping and upon completion of disposal. In addition, samples of arriving materials are taken to ensure manifests are correct and to provide base line information.

The decontamination process includes removal of visible material from interior and exterior surfaces. All rail cars are tested for removable contamination. The rail cars are decontaminated as necessary prior to release. The decontamination involves hand tools and /or water as needed. Waste water is used for dust suppression on various embankments.

4.1.3.3 UMTRA Cleanup (Grand Junction, Colorado). The containers at the Grand Junction uranium tailings cleanup operation are washed immediately after disposal with high pressure water hoses and monitoring is conducted prior to release. In addition, after unloading the tailings, the exteriors of the containers and the trucks are washed prior to placement on the rail car. This ensures a relatively "clean" car. In addition surfactants are added to the containerized waste surface to ensure stability and minimize fugitive dust.

4.1.3.4 Uranium Mines. Uranium mining operations were contacted about their experience with decontamination of rail cars. In general, the uranium ore is not considered a dangerous or regulated material and decontamination is not required. However, persons associated with the operation of the rail cars indicated that there was a tendency for the cars to build up accumulations of soil because of rough surfaces in many locations on the cars. These areas of accumulation include the wheels, couplings, seams and any structural plates added for strength (Smith 1993). Consequently, the rail cars will present problems if decontamination were required.

4.1.4 Summary

The conveyor has relatively simple decontamination requirements. Washing of the conveyor once a week with low pressure water has proven acceptable on other projects.

The decontamination experience of 4 hours for decontamination at T-Plant may be a more rigorous operation than what will be required for decontamination of rail cars (such as the rotator coupler) that may be used to transport remediation wastes to the ERDF, but T-Plant may be closer to the time required than the UMTRA time requirements. A protracted decontamination appears likely because of the roughness of the rail car surface and the presence of an undercarriage that will make automated systems impractical. Additionally, the rough surface and hard to reach areas of the undercarriage will require larger quantities of water to accomplish the cleaning. Consequently, it is anticipated that the rail car alternatives will require significantly longer decontamination as compared with decontamination of containers. The time required may be as much as 4 hours per car which will make use of these alternate rail cars impractical.

4.2 BENEFICIAL USE OF EXCAVATED MATERIAL

4.2.1 Introduction

The ERDF will require soil materials for the liner, Hanford Barrier, surface and interim covers, operation layer, and earth embankment. Some of these materials can be supplied either directly by material from the trench excavation or by processing of the material from the trench excavation. This portion of the study evaluates the quantities of operation and closure material which could economically be provided by material from the required excavation. The remaining sorted material will be either available for back haul to the operable unit remediation site for use in restoration landscaping or for site grading at the ERDF. For more information, see the Materials Balance Evaluation Technical Memorandum (Appendix E) in the *Design Memorandum Report for the ERSDF* (COE 1993b).

4.2.2 Volume of Materials Excavated from Trenches

The trench configuration assumed for quantities included two different layouts to provide a disposal capacity of 28.5 million yd³ each. The first layout consisted of 2 trenches 1,200 feet wide and 14,250 feet long at the surface. The second layout consisted of 1 trench 1,420 feet wide and 10,700 feet long at the surface. The first layout was 33 feet deep and the second layout was 70 feet deep. Both trench layouts have side slopes of 3H:1V (horizontal to vertical). The first trench layout requires 23.1 million yd³ of excavation and the second trench layout requires 25.5 million yd³ of excavation. The trenches are aligned from east to west and are located in the northern portion of the ERDF site. The soil stratigraphy used in computing the quantities of material having various soil gradations was based on particle size analyses available on the ROCKSAN database. In addition, gradations from *Engineering Study for the Trench and Engineered Barrier Configuration for the ERSDF* (COE 1993a) of material from a gravel pit located to the north of the proposed trenches were used. Appendix J presents the supporting earthwork mass balance calculations.

4.2.3 Usable Materials from Trench Excavation

As indicated *Engineering Study for the Trench and Engineered Barrier Configuration for the ERSDF* (COE 1993a), fine silty sand would be suitable for liner material. The materials from the trench excavations that could be used in the Hanford Barrier would require processing. These materials include silt, filter sand, pea gravel, filter rock, drain rock, and capillary break rock. It is believed that any excess material not used as liner material or in the Hanford Barrier would be suitable for the surface and interim cover, operation layer, and earth embankment.

4.2.4 Cost Comparison Between Excavation Material and Other Sources

The available materials from each trench excavation that will be suitable for trench construction are listed in Table 5. Also included in the table are the required quantities of the suitable materials and an approximate cost for each material type. Cost data was based upon the *Engineering Study for the Trench and Engineered Barrier Configuration for the ERSDF* (COE 1993a).

4.2.5 Cost Savings to the Government

As indicated by review of Table 5, some materials from the trench excavations could be used for trench construction at a cost savings to the government while other materials will be more costly (silt and pea gravel). The cost savings to the Government will be \$18.61 million for the layout with two trenches and \$12.43 million for the layout with one trench. The remaining volume of material could be back hauled to the operable unit for use in restoration of the remediation site. The volume of backhaul material was 11.1 million yd³ for the layout with two trenches and 17.44 million yd³ for the layout with one trench.

4.2.6 Back-Haul to Remediation Sites

Since the rail cars will be returning to the remediation sites, it may be economical to use the rail cars for back-haul of the excess materials. The material can be hauled in the decontaminated containers as long as the containers are decontaminated to meet appropriate regulations as discussed in the *Engineering Study for the Decontamination and Wastewater*

Table 5. Material Cost and Volume Estimates.

Material	Source	Unit Cost (per yd ³) (see note 1)		Volume, for Alternative 1 (million yd ³)		Volume, for Alternative 2 (million yd ³)		Cost Savings (million \$)	
		Imported	On-Site Processing	Required	Available	Required	Available	Alternative 1	Alternative 2
Admixing Soil (Liner)	Sandy Sequence	N/A	\$0.00	2.19	15.00 see note 2	1.78	17.17 see note 2	N/A	N/A
Silt (Hanford Barrier)	Sandy Sequence	\$8.00	\$12.00	8.40	5.78	3.67	6.88	N/A	N/A
Filter Sand (Hanford Barrier)	Sandy Sequence	\$10.00	\$6.00	0.69	13.86 see note 2	0.30	15.88 see note 2	2.76	1.20
Pea Gravel (Hanford Barrier)	Upper Gravel	\$6.50	\$16.00	0.69	see note 3	0.30	see note 3	N/A	N/A
Filter & Drain Rock (Hanford Barrier)	Upper Gravel	\$6.50	\$6.00	2.75	1.53 see note 2	1.22	1.30 see note 2	0.77	0.61
Capillary Break (Hanford Barrier)	Upper Gravel	\$26.00	\$16.00	6.89	0.60	3.04	0.51	6.00	5.10
Random Cover	Sandy Sequence	\$1.30 see note 4	\$0.00	1.90	18.09 see note 2	1.57	19.16 see note 2	2.47	2.04
Operational Layer	Sandy Sequence	\$1.30 see note 4	\$0.00	2.24	15.85 see note 2	1.61	17.59 see note 2	2.91	2.09
Embankment	Sandy Sequence	\$1.30 see note 4	\$0.00	2.85	13.00 see note 2	1.07	15.98 see note 2	3.70	1.39
Notes						Total Savings		\$18.61	\$12.43

1. Price information came from Table 1 of COE 1993a.
2. The gradation for the indicated material overlaps the gradation of other material items and the quantity shown as "available" would be reduced if the overlap was excluded. But, because of the relatively small volume "required", the competing demands for gradations that overlap should not result in being unable to produce the required volume of all materials except as noted.
3. Pea gravel can not be provided because of the overlapping gradation requirement of filter and drain rock.
4. Cost of imported random material based upon assumed hauling of 1 mile.

N/A: Not applicable.

Treatment Facility for the ERSDF (COE 1993d). Alternatively, dedicated containers could be utilized although their cost could be substantial. The back haul of this material is currently not required by the FDC. However, the remediation sites could use up to 1 million yd³ of material (Langstaff, 1993) so backhaul facilities will be incorporated into the design of the ERDF. All material in excess of the 1 million yd³ will be graded as needed for permanent placement in the ERDF.

4.3 MAINTENANCE SUPPORT

With the types of equipment proposed and with the capacity of the equipment, the maintenance of the equipment can easily be performed during weekends and during off-shift hours.

4.4 CONCLUSIONS AND RECOMMENDATIONS

The following are the conclusions and the recommendations of this Section:

- The conveyors can be easily decontaminated using water.
- The decontamination of rail cars will be protracted and may be as much as 4 hours per car which will make use of these alternate rail cars impractical. Therefore, it is recommended to continue design based on use of removable containers mounted on flat bed rail cars.
- The use of excess materials from the trench excavation for the liner and Hanford Barrier, surface and interim covers, operations layer, and earth embankment is highly recommended. Material for the covers and liner is readily available and abundant. Use of the excavated material could save \$9.5 or \$6.9 million depending on the trench layout.
- The material must be back-hauled to the remediated sites in accordance with relevant codes.
- The routine maintenance of the equipment can be easily accomplished during weekends and off-shift working hours.

5.0 COMPARISON OF TRANSPORTATION ALTERNATIVES

The two methods of transportation of waste material to the trench are described in Sections 5.1 and 5.2. These methods are truck transportation (COE 1993c) and mechanical conveying (see Section 3.3). These methods include placement of materials in the trench without compaction costs. Compaction issues were presented in Section 2.3.

Comparisons based both on cost (capital cost, operation and maintenance cost, and present worth cost) and on qualitative comparisons are summarized in Sections 5.3 and 5.4.

5.1 WASTE MATERIALS TRANSPORTATION BY TRUCK ALTERNATIVE

The waste materials transportation by truck alternative is discussed under the heading Section 2.3.5.2, Truck Haul to Top of Trench, of the *On-Site Transportation Network Engineering Study for the ERSDF* (COE 1993c). Figure 7 depicts the process flow diagram for truck haul of a reusable container from the railhead directly to the working face at the top of the disposal trench. As the trench is filled, the point of dumping into the disposal trench advances with the placement of waste materials.

Reusable containers will be transferred to trucks at the railhead and transported along a waste haul road. The haul road in the immediate vicinity of the disposal trench will be constructed outside of and parallel to the trench axis. A spur haul road will extend from the haul road to the working face. At the working face, trucks will approach the working face on cover material placed over the waste material. Waste material transported to the top of the cell will be placed using the pyramid construction method.

The conventional trench disposal alternative, as recommended in the *On-Site Transportation Network Engineering Study for the ERSDF* (COE 1993c), was called "Pyramid Construction". This alternative is depicted in Figure 8. The waste placement area will be divided into two levels: the top level will be approximately 10-feet high and the lower level will be approximately 23-feet high. Under this waste placement method, all waste-carrying trucks will deposit the waste into the lower level of the upper zone and not onto the existing cover materials. The waste will then be dozed in the lower level and the cover extended by dozing cover material over the exposed waste materials at the top level of the trench.

The *On-Site Transportation Network Engineering Study for the Environmental Restoration Storage and Disposal Facility* (COE 1993c) recommended that the waste hauling trucks be compatible with the equipment used at the remediation sites, which is anticipated to be similar to those used at the UMTRA site in Grand Junction, Colorado. Those trucks and trailers are anticipated to cost \$110,000 each. Cycle time, railhead to trench tipping face and back to railhead, at an average speed of 25 miles per hour (mph), 2-mile maximum travel, with a 3-minute loading, 1-minute layover, and 3-minute dump will be 17 minutes per cycle. This cycle time will require 7 units during peak demand and maximum travel.

The transfer of containers from the rail cars to the trucks will be by wheeled container loaders. This equipment will be forklift-type vehicles fitted with a top-attaching container grabber with 100,000-pound capacity (equivalent to Taylor Machine Works, Inc. model TETC-1100-20.) This equipment will lift the container from the train and then back up to allow the approach of a truck/trailer unit to a position between the container loader and the rail car. The loader will then place the container on the truck/trailer, then the loaded truck will depart. The cycle will be repeated, including advance to the loading position for the next container. The rail

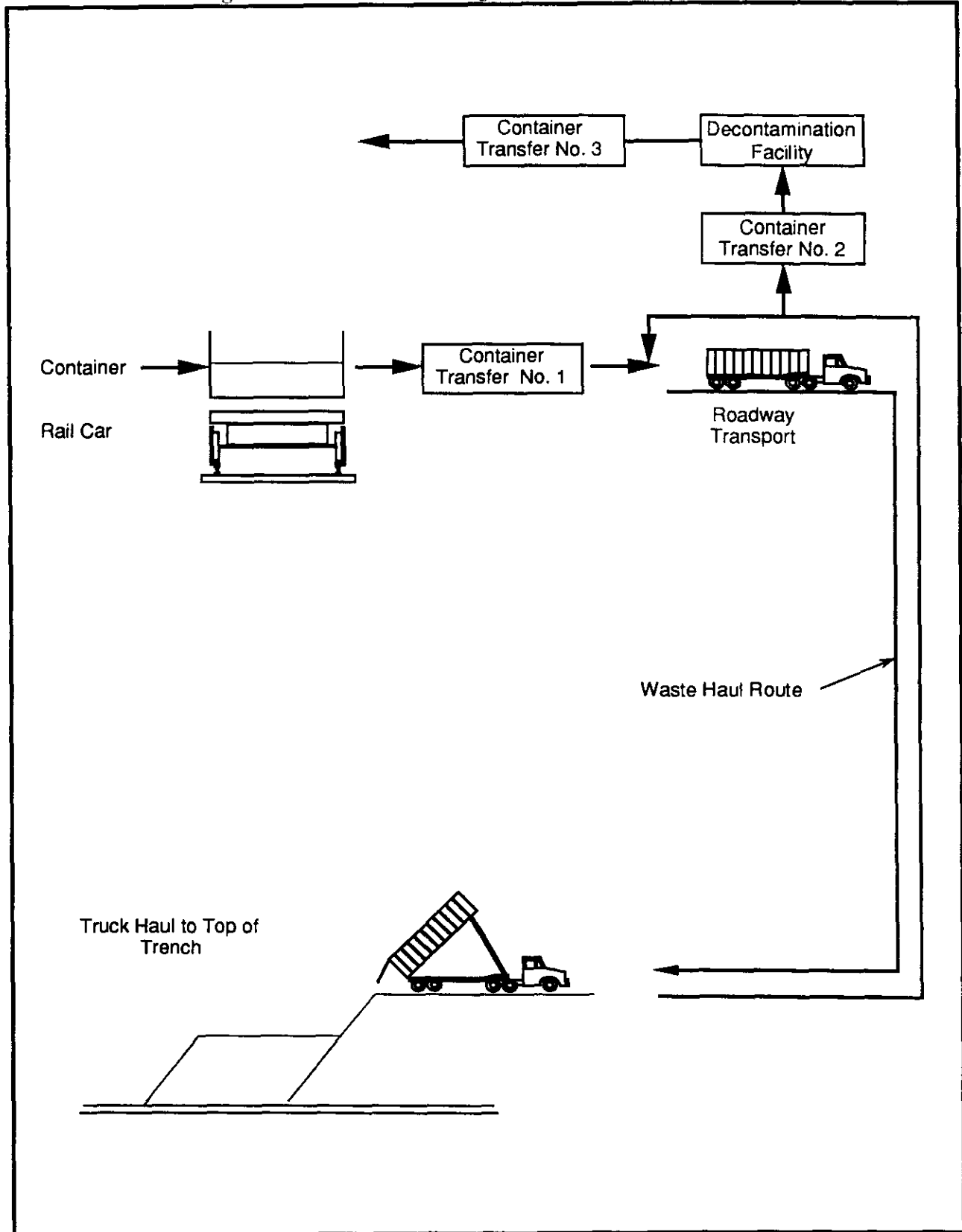
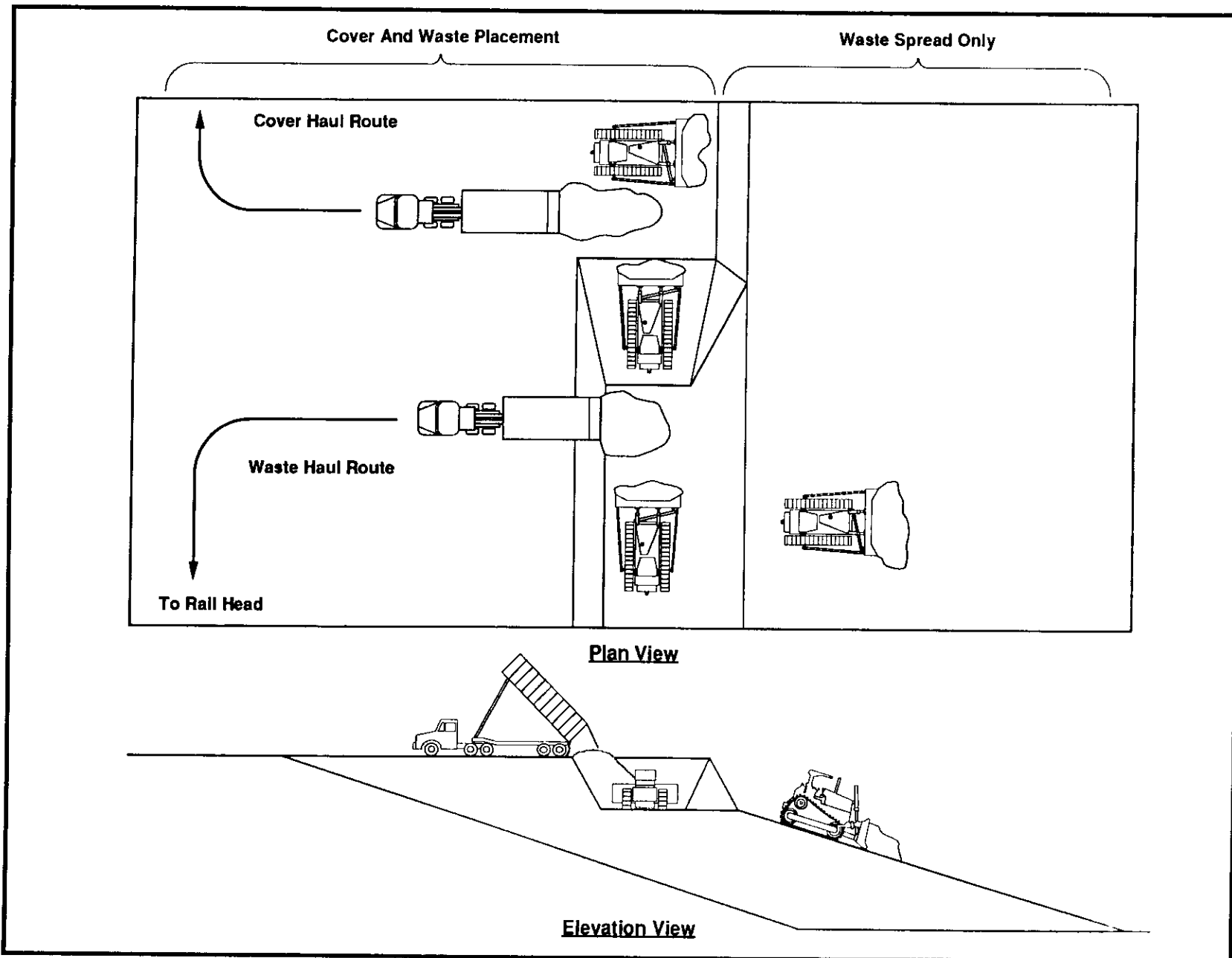
Figure 7. Process Flow Diagram - Truck Transportation.

Figure 8. Pyramid Construction.



cars will not be moved until the entire train has been emptied. Operation will require construction of a pad extending the length of the rail car train. Processing capacity is estimated at 2.5 minutes per container or 192 containers per 8-hour shift. The cost of each unit is estimated at \$380,000. One unit plus a standby unit will be required at the railhead to accommodate unloading of containers.

Under this option, truck haul roads within the disposal cell will be limited to covered areas at the top level of the trench and haul distances over waste deposit areas will be held to a minimum. Intermediate cover materials will not be used and therefore will not displace waste materials in the trench.

The transfer of empty containers from the trucks to the decontamination facility is currently anticipated to be another wheeled container loader although a slide off box arrangement could be used. Since the containers are empty, a smaller, 25,000-pound capacity, wheeled container loader could be used. At the entrance of the decontamination facility, the loader will lift the empty container from the truck and place it on the conveyor system into the decontamination facility. Processing capacity is estimated at 2.5 minutes per container or 192 containers per 8-hour shift. At the exit of the decontamination facility, the decontaminated containers will be staged under a cover. A second loader will pick up each container and place it on the nearest rail car. Processing capacity is estimated at three minutes per container or 160 containers per 8-hour shift. Some overtime may be needed to process all 175 containers. Operation will require a small pad at the entrance of the decontamination facility and construction of a pad extending the length of the rail car train at the exit of the decontamination facility.

With the multiple waste handling vehicles (an average of 22 truck trips per hour) on gravel roads, dust control will be needed. For this analysis, the roads were paved as much as possible.

Under this alternative, the following equipment will be required:

- One 100,000-pound capacity wheeled container loader plus a standby unit for loaded containers;
- Two 25,000-pound capacity wheeled container loaders plus a standby unit for empty containers;
- Seven waste-transport trucks plus a standby truck;
- One dozer plus a standby dozer for cover material on top of the trench; and
- Two remote controlled dozers plus one standby dozer for moving material in the trench.

Under this option, there will be 3 operators, 1 dozer operator, 2 remote dozer operators, and 7 truck drivers.

5.2 WASTE MATERIALS TRANSPORTATION BY CONVEYING ALTERNATIVE

This alternative is described in Section 3.3 of this report and is shown on Figures 3, 4, 5, and 6.

5.3 COMPARISON OF COSTS

5.3.1 Capital Costs

The cost estimate should be considered as "order-of-magnitude" with a probable accuracy of plus or minus 40 percent. Maintenance equipment, as well as rail car moving equipment, are not included in the capital cost estimate.

All buildings and conveyors were assumed to have a 22-year life so no replacement costs were included. At the end of the 22-year project life, these items will have no salvage value. All mobile equipment (trucks, loaders, dozers) in constant use were assumed to have an 8-year life, so replacement is required twice during the 22-year project life. The trucks used to haul "out of bounds material" under the conveyor option were assumed to only be used for 4 months per year and were replaced at the end of a 16-year life. At the end of each equipment life, the equipment was assumed to be buried in the trench as the cost of decontamination was assumed to be greater than the salvage value.

The indirect costs include allowances for Construction Permits (2 percent), Engineering and Construction Management (15 percent) and Contingencies (15 percent). These percentages compound to 35 percent.

5.3.1.1 Capital Costs for Waste Materials Transportation by Truck. Table 6 presents the estimated capital cost for this alternative.

5.3.1.2 Capital Costs for Waste Materials Transportation by Conveyor. Table 7 summarizes the estimated capital cost of the conveyor system. Four phases of construction are indicated to represent the phases of construction of the landfill transport conveyor. The year denotes the year the extension will be placed in service.

5.3.2 Operating and Maintenance Cost

In order to compare the alternatives, the following unit costs were assumed for the various operating and maintenance categories:

Equipment operators (Based on WHC 87301 category)	\$40/hour
Maintenance labor	\$40/hour
Electricity	\$0.027/kilowatt hour
Diesel fuel	\$1.00/gallon
Surfactant	\$8.00/gallon
Equipment maintenance cost	3% of equipment cost
Building maintenance cost	3% of building cost
Insurance cost	\$1.50 per thousand

The "personnel per shift" is the estimated number of people required to operate or maintain the system excluding administrative and management personnel. No administrative and management personnel were included as these were assumed to be similar with each alternative.

5.3.2.1 Operations and Maintenance (O&M) Costs for Waste Materials Transportation by Truck. Table 8 presents an estimate of operating and maintenance costs for two levels of annual throughput.

Table 6. Capital Cost Estimate For Waste Materials Transportation by Truck.
(Thousand \$)

Item	Quantity	Unit Cost	1997 Cost	2005 ^a Cost	2013 ^a Cost	Total Project Cost
100,000 lb Capacity Wheeled Loaders	2	\$380	\$760	\$965	\$1,226	\$2,961
25,000 lb Capacity Wheeled Loaders	3	150	450	571	725	1,746
Waste Transport Trucks	8	110	880	1,118	1,420	3,418
Dozers to Place Cover	2	260	520	660	839	2,019
Remote Operated Dozers to Spread Waste	3	340	1,020	1,300	1,645	3,965
Rail Car Unloading Pad	30,000 sf	1.50	45	57	73	175
Truck Unloading Pad	4,000 sf	1.50	6	8	10	24
Rail Car Loading Pad	30,000 sf	1.50	45	57	73	175
Roads (Paved)	15,000 lf	2.50	<u>940</u>	<u>0</u>	<u>0</u>	<u>940</u>
Subtotal			4,666	4,736	6,011	15,413
Contingency, Engineering and Administration (35%)			<u>1,634</u>	<u>1,657</u>	<u>2,104</u>	<u>5,395</u>
Total Capital Cost			\$6,300	\$6,393	\$8,115	20,808

^aInflation assumed to be 3% per year or 27% in 8 years.

Table 7. Capital Cost Estimate For Waste Materials Transportation by Conveyors.
(Thousand \$)

	1997 ^a Cost	2001 ^a Cost	2005 ^a Cost	2009 ^a Cost	2013 ^a Cost	Total Project Cost
Site Paving & Utilities	\$400	\$100	\$100	\$100		700
Container Unloading Building	800					800
Screening/Agglomerating Building	300					300
Processing Equipment	2,000					2,000
Distribution Conveyor	600	340	380	430		1,750
Placing Conveyor/Machine	2,300					2,300
Dust Control Equipment	900					900
Electrical & Controls	800	110	130	150		1,190
100,000 lb Capacity Wheeled Loaders	1,140		1,450		\$1,840	4,430
25,000 lb Capacity Wheeled Loaders	450		570		720	1,740
Dozers to Place Cover	520		660		840	2,020
	550	---	---	---	890	1,440
Subtotal	10,760	550	3,290	680	4,290	19,570
Contingency, Engineering and Administration (35%)	3,770	190	1,150	240	1,500	6,850
Total Capital Cost:	14,530	740	4,440	920	5,790	26,420

^aInflation assumed to be 3% per year.

Table 8. Operation and Maintenance Costs for Waste Materials Transportation by Truck.

Annual Volume (1,000 yd ³ units)	1,340	2,010
Operating Shifts per Year	250	375
Containers per Shifts (32 yd ³ /container)	168	168
Container Wheeled Loaders in Service	3	3
Waste Hauling Trucks in Service	7	7
Cover Spreading Dozers In Service	1	1
Waste Spreading Dozers (Remote Operated)	2	2
Operation Personnel Per Shift	13	13
Maintenance Personnel Per Shift	2	2
Annual Operating Hours	2,000	3,000
Annual Labor (Hours)	30,000	45,000
Annual Fuel Consumption (Gallons) ^a	260,000	390,000
Labor Cost (\$1,000)	\$1,200	\$1,800
Fuel Cost (\$1,000)	260	390
Road Maintenance Cost (\$1,000) ^b	40	40
Insurance (\$1,000)	10	10
Maintenance (\$1,000)	<u>123</u>	<u>123</u>
Total O&M Cost (\$1,000)	\$1,633	\$2,363
O&M Cost per Cubic Yard	\$1.22	\$1.18

^aAnnual Operating Hours x number of units x 10 gallons per hour

^b15,000 linear feet of road x 25-feet wide x \$0.10 per square foot per year

Table 9. Operation and Maintenance Costs for Waste Materials Transportation by Conveyors.

Annual volume (1,000 yd ³ units)	704	1,340	1,680	2,010
Operating shifts per year	250	250	300	375
Containers per shift	88	168	168	168
Installed conveyor phases	1	2	3	4
Container wheeled loaders in service	3	4	4	4
Trucks hauling over-sized materials ^a	1	1	1	1
Trucks hauling "out-of-bounds materials" ^b	2	4	4	4
Cover spreading dozers in service	1	1	1	1
Full-time operating personnel per shift	7	8	8	8
Seasonal truck drivers (4 months/year)	2	4	4	4
Maintenance personnel per shift	3	4	4	4
Annual system operating hours	2,000	2,000	2,400	3,000
Annual labor hours	21,333	26,667	32,000	40,000
Equipment utilization ^c	35%	70%	70%	70%
Installed electrical horsepower	1,350	1,550	1,750	1,950
Annual fuel consumption (gals) ^d	93,300	146,700	176,000	220,000
Annual power consumption (mwh) ^e	709	1,628	2,205	3,071
Annual surfactant solution (1,000 gals) ^f	1,369	2,722	3,266	4,082
Labor cost (\$1,000)	853	1,067	1,280	1,600
Fuel cost (\$1,000)	93	147	176	220
Power costs (\$1,000)	19	44	60	83
Surfactant solution (\$1,000)	11	22	26	33
Insurance (\$1,000) ^g	20	22	23	24
Fixed maintenance (\$1,000) ^h	381	417	438	459
Running maintenance (\$1,000) ⁱ	78	85	88	92
Total O&M cost (\$1,000)	\$4,555	\$1,804	\$2,091	\$2,511
Operation and maintenance cost/yd ³	\$2.07	\$1.35	\$1.25	\$1.25

^aBased on 18% of 84% of annual volume^bBased on 16% of annual volume^cAnnual volume (operating shifts x 8 hours x 1,000 yd³ per hour)^dAnnual operating hours x number of units x 10 gallons per hour^eMegawatt hours = 0.75 x horsepower x annual operating hours x utilization.^fSurfactant solution (gals) (1% moisture by weight) = annual volume x 0.60 x 3.24 gallons/yd³^gInsurance cost = \$1.50 per thousand of capital cost^hFixed maintenance cost = 3% of capital costⁱRunning maintenance = 1% of mechanical & electrical cost per 1,000 hours of operation

5.3.2.2 Operation and Maintenance Costs for Waste Materials Transportation by Conveyor. Table 9 summarizes an estimate of operating and maintenance costs for four levels of annual throughput. The installed conveyor phases represents the number of segments of distribution conveyor (which feeds the walking conveyor) installed.

5.4 PRESENT WORTH COMPARISON OF WASTE MATERIALS TRANSPORTATION

For the present worth calculations, the interest rate was selected at 8.25 percent which is the Federal Discount Rate for Fiscal Year 1993. This rate was computed in accordance with Section 80 of Public Law 93-251.

Table 10 presents the present worth of the two transportation alternatives based on 2.01 million yd³/year.

Table 10. Present Worth Comparison of Transportation Alternatives.

Costs	Truck Transportation	Conveyor Transportation
Present Worth of Capital	\$11,981,000	\$19,418,000
Present Worth of Annual O&M Cost	\$23,654,000	\$25,135,000
Total Present Worth	\$35,635,000	\$44,553,000

The present worth cost of the truck transportation alternative is 25 percent less than the present worth cost of the conveyor transportation alternative.

5.5 COMPARISON OF ADVANTAGES AND DISADVANTAGES OF TRANSPORTATION ALTERNATIVES

Truck transportation has a 25 percent lower present worth cost than conveyor transportation.

The conveyor alternative requires fewer staff than the truck alternative (12 full-time plus 4 part-time versus 15), but the staff will need to be more highly trained than the staff of the truck alternative due to the types of equipment.

The truck alternative utilizes the same equipment as at the remediation sites which makes for a more easily maintained system. Interchangeability of equipment is better with the truck alternative.

The conveyor alternative requires a separate system to handle oversized, burial ground wastes, mixed wastes, and single-use containers, whereas the truck alternative utilizes the same equipment for all materials. The truck alternative also eliminates the need for source separation at the remediation sites.

In the conveyor alternative, during dumping of container, the exterior of the container may become contaminated. When placed back on the rail car, it could contaminate the rail car necessitating expensive rail car decontamination.

In the Technical Memorandum Automation Strategy Development of the *Design Memorandum Report for the ERSDF* (COE 1993b), it has been recommended that the final location of the waste in the trenches be recorded in the computer data bank. This may be more easily accomplished with the truck alternative than with the conveyor alternative.

In the truck transportation alternative, the truck drivers will be in the proximity of the waste. However, due to the shielding provided by distance from the container to the truck and shielding that can be built into the truck cab, this is not a concern. This handling of material is the same as at the remediation sites. In the conveyor option, whenever a conveyor, vibratory screen, agglomerator, or other equipment item needs maintenance, it must be decontaminated which is easily done with water. However, this water then needs to be treated and disposed.

Many of the components of the mechanical conveying system are provided with redundant units. However, the distribution and placement conveyors do not have redundant units. The overall reliability exceeds the required 67 percent, but if a conveyor fails, the trench operation will be stopped until repairs are completed. The containers can be removed from the rail cars and temporarily stored on the ground to allow the rail cars to be reused. When the conveyor is repaired, the system will then operate at 100 percent efficiency until the stored containers are all emptied. With the truck transportation system, if a truck breaks down, it can be readily replaced so double handling of the containers is not required.

The FDC (WHC 1993b) requires that the ERDF operate 2 shifts per day for 6 months per year, and 1 shift per day for the other 6 months per year. This is a 670 yd³/hr handling rate. The conveyor and placement system as proposed can handle approximately 800 yd³/hr. If the conveyor system was increased to 1,700 yd³/hr, only one shift per day will be needed year round. Additional capital costs would be required but the operating cost would be reduced as only one shift would be required. This extra capacity will be unusable during the winter.

To handle all the waste in one shift year round at 17 minutes per round trip and 42 containers per hour (1,344 yd³/hr), would require 12 trucks (instead of 6). This would require additional capital for the additional trucks. Operating cost would be only slightly reduced as only supervisory and wheeled container loader operator labor would be reduced.

For the above reasons, truck transport is recommended.

5.6 RECOMMENDATION

It is recommended that waste materials should be conveyed by truck from the railhead to the trenches.

6.0 COMPARISON OF TRENCH CONFIGURATION

In this section, various trench widths and depths are compared.

6.1 COMPARISON OF TRENCH CONFIGURATIONS AND COSTS

6.1.1 General

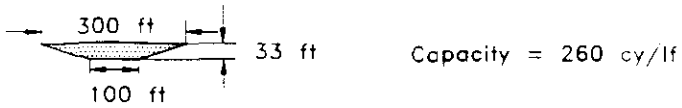
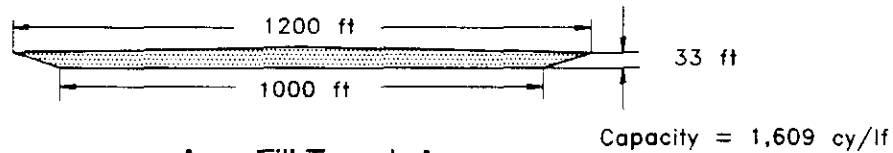
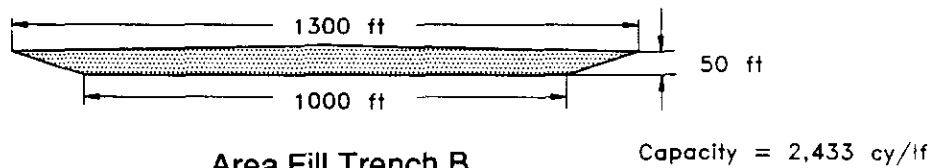
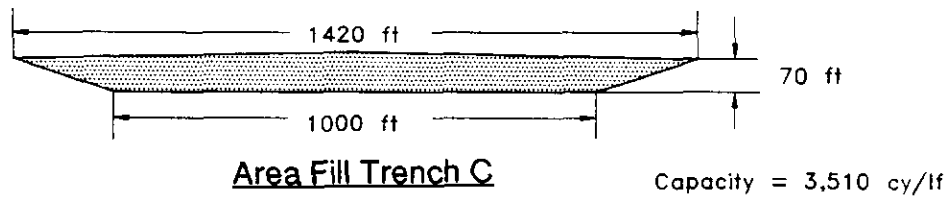
The purpose of this section is to compare the areas and costs for three area fill trench configurations and the base case trench configuration for the ERDF. The required trench capacity is assumed to be 30.5 million yd³, comprised of 28.5 million yd³ of waste and an additional 2 million yd³ for daily and interim covers. The trench liner system in all cases is assumed to be a double liner in accordance with RCRA Minimum Technology Requirements (MTRs). Details of the waste volumes and liner system are presented in the *Engineering Study for the Trench and Engineered Barrier Configuration for the ERSDF* (COE 1993a).

The four trench configurations evaluated here are illustrated on Figure 9. The 4 cross-sections are:

- Base case trench, 100-foot trench floor width, 33-feet deep;
- Area fill trench A, 1,000-foot trench floor width, 33-feet deep;
- Area fill trench B, 1,000-foot trench floor width, 50-feet deep; and
- Area fill trench C, 1,000-foot trench floor width, 70-feet deep.

All of the trench configurations have 3H:1V (horizontal to vertical) side slopes and 2 percent crown slopes on the waste surface. The base case trench is the design currently assumed for the ERDF. The area fill trenches have a floor width of 10 times the base case trench, or 1,000 feet. This width was chosen for illustrative purposes and is considered feasible with respect to installing a RCRA compliant leachate collection system within the trench. Greater widths, possibly up to 2,000 feet, may also be feasible. This issue will be evaluated during detailed design when the trench layout is optimized for whichever site is ultimately selected. The conclusions in this section would not be significantly affected if a wider trench was assumed.

Area fill trench A is the same depth as the base case trench at 33-feet below ground surface. This depth limitation reflects potential regulatory concerns and the resulting desire to maintain the waste as high above the groundwater table as practical. Area fill trenches B and C represent deeper trenches and are included for comparison purposes. With respect to constructability and operations, no problems were identified with area fill trenches B and C. Even deeper trenches are feasible and, in fact, have been successfully constructed for commercial landfills. However, the performance of deeper trenches with respect to groundwater protection is currently being evaluated by WHC, and consequently, selection of an optimum trench depth is not possible at this time.

Figure 9. Cross Sections of Potential ERDF Trench Configurations.**Base Case Trench****Area Fill Trench A****Area Fill Trench B****Area Fill Trench C****NOTES**

1. All configurations have 3H:1V side slopes.
2. All configurations have 2% crown on waste surface.

Using the dimensions given above, the capacity per linear foot of trench was calculated. The required trench capacity was then used to calculate the total length of each type of trench that will be needed. These results are presented in Table 11.

Table 11. Trench Capacity and Length.

Trench Configuration	Waste Capacity Per Linear Foot of Trench (yd ³ /linear foot)	Total Length Required (feet)
Base case	260	117,308
Area fill trench A	1,609	18,956
Area fill trench B	2,433	12,536
Area fill trench C	3,510	8,689

6.1.2 Surface Area Requirements

For all configurations, trenches are assumed to be separated by 211 feet. In addition, a zone of 113 feet around the perimeter of the facility has been assumed. These distances provide space for the margin of the Hanford Barrier, access roads, and drainage ditches. Trench layouts are shown on Figure 10. For the base case trench, the layout from the Material Balance Evaluation Technical Memorandum (Appendix E) from the *Design Memorandum Report for the ERSDF* (COE 1993b) was used. For the area fill trenches, the required surface area is based on two parallel trenches to accommodate a conveyor system located on the intervening berm. This configuration also works with truck transportation.

The required areas for each trench configuration are shown on Figure 10 and are plotted as a function of trench depth on Figure 11. The land area required by area fill trench A is less than 45 percent of that required by the base case trench. With deeper area fill trenches, the required area is less than 26 percent of the base case. The reduced land area requirements of the area fill trench will provide more buffer area around the ERDF. It will also reduce security fencing and security monitoring.

The trench layouts used in this analysis represent an example approach for comparison purposes. Actual layouts will depend on site topography, location of transportation and support facilities, etc. and could differ from those assumed here. However, the reduction in surface area and cost provided by the area fill concept is relatively insensitive to details of the lateral dimensions of the landfill, provided that the total surface area is similar to the examples discussed in this section. In addition, the area fill concept is sufficiently flexible to accommodate various locations within the proposed ERDF site, or sites in other areas if necessary.

6.1.3 Liner System Costs

To estimate the liner system unit cost, information from the Project *W-025 Radioactive Mixed Waste Landfill Disposal Facility* (DOE/RL 1992) was used. Costs were escalated by 5 percent to account for inflation, thereby adjusting the 1992 liner system costs to 1993 levels. Table 12 lists the cost per linear foot of trench, the waste capacity, and the resulting liner cost per cubic yard of waste. Figure 12 illustrates the unit liner costs. The unit cost for area fill trench A is about 60 percent of the base case trench cost, while the cost for area fill trench C is about 30 percent of the base case cost. Details of the cost calculations are included in Appendix G.

Given the large volume of waste, differences in unit liner costs can have a significant impact on overall project costs. This is illustrated in Table 13, which shows that even area fill

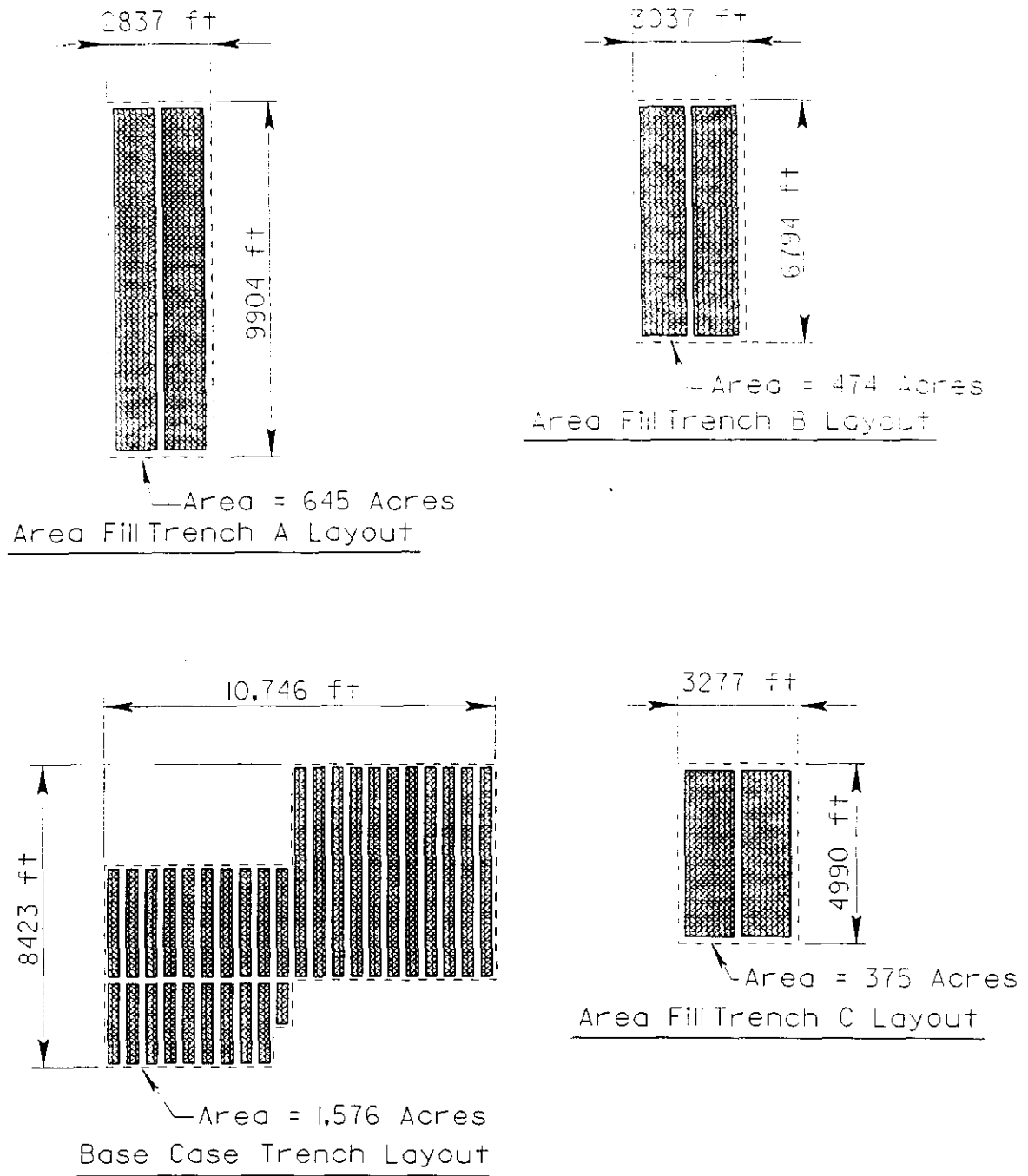
Figure 10. Trench Layout Comparison.

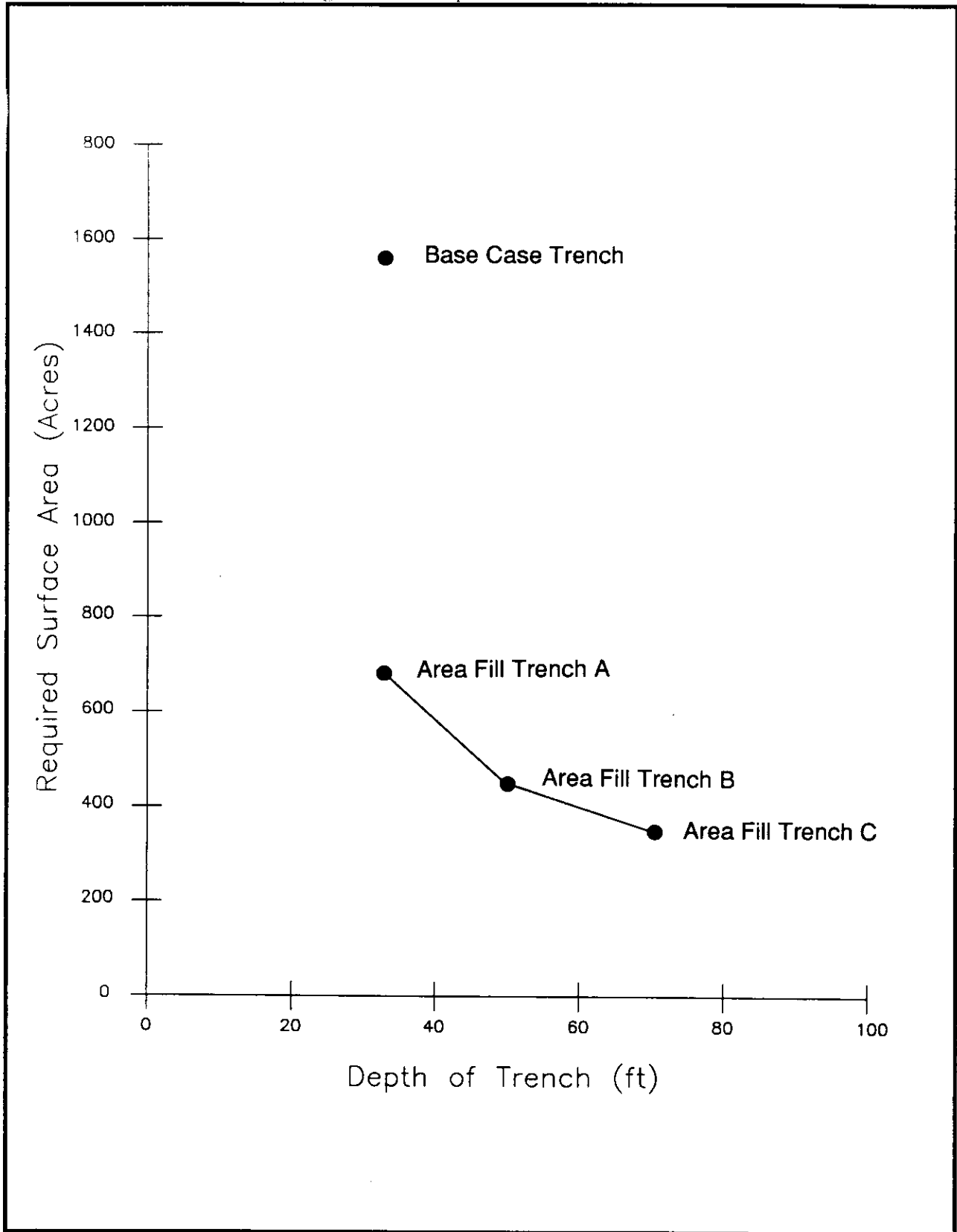
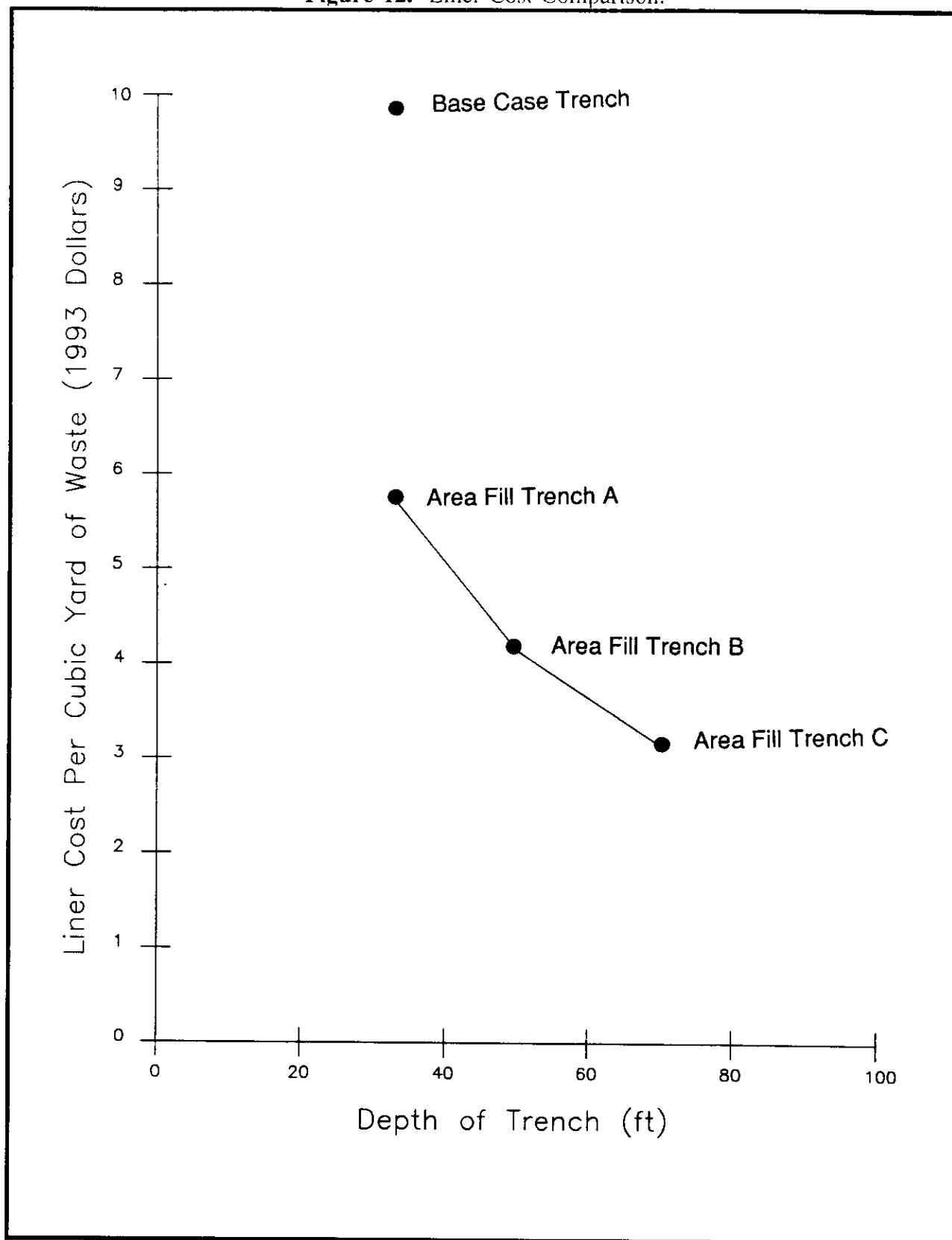
Figure 11. Required Surface Areas.

Figure 12. Liner Cost Comparison.

trench A will save over \$120 million over the base case trench. With the deeper area fill trench C, savings of more than \$200 million have been estimated.

Table 12. Liner Unit Cost Comparison.

Trench Configuration	Cost Per Linear Foot of Trench (\$)	Waste Capacity Per Linear Foot of Trench (yd ³ /linear feet)	Liner Cost Per Cubic Yard of Waste (\$/yd ³)
Base case	\$2,569	260	\$9.88
Area fill trench A	\$9,384	1,609	\$5.83
Area fill trench B	\$10,114	2,433	\$4.16
Area fill trench C	\$10,970	3,510	\$3.13

Table 13. Total Liner Cost Comparison.

Trench Configuration	Total Liner Cost for 30 Million yd ³ of Material	Cost Savings From Base Case
Base case	\$296,000,000	\$0
Area fill trench A	\$175,000,000	\$121,000,000
Area fill trench B	\$125,000,000	\$171,000,000
Area fill trench C	\$94,000,000	\$202,000,000

6.1.4 Excavation Cost Savings

Although each trench configuration will store the same volume of material, the excavation costs will vary with the configuration. Each trench configuration will be suitable for the use of large earth moving equipment. However, the area fill trench configuration will be easier to construct due to the ease of maneuvering equipment in the wider trench. Also, much less side slope shaping will be required with the area fill trench A (4.3 million ft² versus 24.8 million ft²). The costs for fine grading the side slopes are included in the liner costs. The costs for coarse grading and excavating the side slopes will be less for area fill trench A than for the base case trench.

The excavation costs are affected by the haul distance to the stockpile area. If the material will be stockpiled at the lower right edge of the base case trench layout, the average haul distance will be 4,300 linear feet. If the material will be stockpiled at the right center edge of the area fill trench A layout, the average haul distance will be 3,000 linear feet. This reduced haul distance will reduce the excavation costs.

It is estimated that the reduced haul distances and reduced side slope grading of the area fill trench A configuration will save \$22 million of the construction cost of the base case trench.

6.1.5 Hanford Barrier Cost

In addition to the savings in the liner cost, the smaller the trench area, the smaller the area that needs the Hanford Barrier. The area and costs of the Hanford Barrier will be significantly reduced with area fill trench concept. The cost of the Hanford Barrier for the four trench configurations are presented in Appendix H. This assumes that either area fill trench A or the base case trench is covered when the entire project is complete and not in phases. If the Hanford

Barrier is constructed in phases the total cost will be higher but the relative savings will be similar to those shown below.

The Hanford Barrier is estimated to cost \$983 million for the base case trench, and \$402 million for area fill trench A, \$271 million for area fill trench B, and \$207 million for area fill trench C. Therefore the area fill trench A configuration will save \$581 million of the construction cost of the Hanford Barrier for the base case trench.

6.1.6 Transportation Cost Savings

The transportation of the waste to the trenches will be affected by the trench configuration. The use of conveyors is practical only with the area fill trench configuration. It would not be economical with the base case trench layout.

An analysis of the truck haul roads in each of the base case trench and area fill trench A configuration determined there would be a \$2 million savings in road construction cost by using the area fill trench A configuration. Also, due to shorter haul distances, one less truck and driver would be needed with the area fill trench A configuration than with the base case trench configuration.

6.1.7 Savings Due to Elimination of RCRA-Compliance

All the costs shown in Table 13 are for a lined trench that meets RCRA requirements. If the regulations allow use of unlined trenches for either all or a majority of the wastes, most if not all of the \$296 million of the base case liner cost can be saved. If the liner is not required, the cost savings associated with the area fill trench concept are reduced. There will be no liner savings but there will be significant savings in land area used and in cost of constructing the Hanford Barrier. These benefits alone justify implementing the area fill trench concept.

The RCRA liner system requires the side slopes to be constructed on a 3H:1V slope. If the liner is not required, the sideslopes can be steepened to 1.5H:1V. If the same top of trench width is used, then more waste volume per linear foot of trench is available. Table 14 indicates the additional volume available with the steeper slopes.

Table 14. Waste Capacity per Linear Foot of Trench (Cubic Yards/Linear Foot).

Trench Configuration	Lined Trench 3H:1V Sideslopes	Unlined Trench 1.5H:1V Sideslopes
Base case	260	320
Area fill trench A	1,609	1,670
Area fill trench B	2,433	2,580
Area fill trench C	3,510	3,780

In terms of land area and the cost for the Hanford Barrier, removing the requirement of the liner saves 23 percent for the base case, 4 percent for area fill trench A, 6 percent for area fill trench B, and 8 percent for area fill trench C. The only significant effect is the increased storage volume of the base case alternative.

6.2 COMPARISON OF COSTS

6.2.1 Capital Costs

The cost estimate should be considered as "order-of-magnitude" with a probable accuracy of plus or minus 40 percent.

6.2.2 Capital Costs for Trench Configuration

These costs are presented in Section 6.1.

6.3 CONCLUSIONS AND RECOMMENDATIONS

The following are the conclusions and recommendations of this section.

- The conveyor transport is only practical with the area fill trench layout.
- Area fill trench A will utilize 45 percent of the land area of the base case trench. This will provide more buffer area and reduce security fencing and security monitoring.
- Area fill trench A will save \$121 million of the liner cost of the base case trench.
- Area fill trench A will save \$22 million of the excavation cost of the base case trench.
- Area fill trench A will save \$581 million of the Hanford Barrier cost for the base case trench.
- Area fill trench A will save \$2 million of the base case road construction costs and will require one less truck and driver for on-site transfer of containers.
- Area fill trench C will utilize 21 percent of the land area of the base case trench. This will provide more buffer area and reduce security fencing and security monitoring.
- Area fill trench C will save \$202 million of the liner cost of the base case trench.
- Area fill trench C will save over \$22 million of the excavation cost of the base case trench.
- Area fill trench C will save \$776 million of the Hanford Barrier cost for the base case trench.
- Area fill trench C will save \$2 million of the base case road construction costs and will require one less truck and driver for on-site transfer of containers.

- Based on the above, area fill trench configuration C is recommended for implementation and for further discussion with the regulatory agencies.
- Eliminating the requirement for the RCRA liner will save \$296 million of the base case trench liners and \$175 million of the area fill trench A liner. It will also increase the storage volume of the base case by 23 percent and by 4 percent for area fill trench A. This also reduces the required area and the cost of the Hanford Barrier.

7.0 SUMMARY AND RECOMMENDATIONS

The following is the summary and recommendations of this report:

Section 2 discusses the impact of the type of waste and how it is placed and compacted on the design of the trenches with the following recommendations:

- The issue of using unlined or single-lined trenches for disposal of waste containing only LLW is presently being negotiated. The cost and required land area for unlined trenches are substantially less than for either of the lined trench alternatives, while the degree of additional performance afforded by the liner systems is minimal. If unlined or single-lined trenches are allowed, they will be allowed for LLW-only waste. RCRA-compliant lined trenches will be required for RCRA hazardous or mixed waste. In this case, a total of 2 trench types will be required. If RCRA-compliant double-liner systems are required for all waste types, then only one type of trench will be employed.
- Radiation protection of workers and the public does not depend on the type or number of trenches, but rather on operational practices, closure cover performance, and/or waste treatment.
- Significant quantities of incompatible wastes are not expected at the ERDF because they are not a large part of the waste inventory, and the incompatible characteristics will be largely eliminated by treatment to satisfy LDRs. If incompatible wastes are received, they will be disposed of in separate cells within the waste trench, isolated by soil or other barriers. Therefore, one RCRA-compliant trench can be used for all waste types.
- Issues associated with long-term groundwater protection will determine whether one or two types of trenches will be used. The total number of trenches will, of course, be a minimum of one of each type; however, a greater number of trenches may be required by construction and operational considerations.
- The main issues of concern when disposing of containerized waste within bulk waste are settlement and breaching of the containers which could release reactive substances. To minimize settlements, containers need to be spaced at least 2 feet apart to avoid soil bridging between containers and the containers should not be stacked. The materials within the container must have a high enough density through either compaction while inside the container or by addition of grout to support the overburden. As long as the materials in the container have sufficient strength to support the overburden and the void space within the containers is minimized, failure of the container is not a concern. Quality control at the remediation sites will be required to verify that the container contents meet the above.
- Reactive materials should be tracked and analyzed by qualified personnel to determine potential hazards. The breaching of radioactive waste containers, which could release reactive substances, is not a concern because the high-activity waste, which is what would normally be placed in the single-use/disposable containers, generally does not have long half-lived radionuclides and the normal process of decay will reduce their potential as a health risk. Additionally, preliminary modeling indicates that none of the cancer-causing contaminants reach the ERDF boundary.

within 10,000 years; consequently, human exposure from groundwater contamination associated with a breach of a container is not a concern.

- Compactable wastes (such as drums or pipes) will be volume reduced at the remediation site. These waste restrictions and processing methods will eliminate waste forms that are likely to cause large settlements.
- Compaction of some type should be performed to reduce the likelihood of unacceptable settlement. Use of vibrating rollers during waste placement is the preferred alternative. Field density tests will be required to determine lift thickness for adequate compaction for a given roller weight, size, operating frequency, and towing speed. The main disadvantage of rolling is worker exposure if high dose rate waste is encountered which can be resolved through the use of remotely-controlled equipment.
- Remote operation of all in-trench equipment is recommended as conditions warrant. The SAR and Operations Plan will set these conditions. Ongoing waste analysis will help determine if remote-controlled equipment is warranted. The additional capital cost associated is relatively small and the safety is greatly improved. These products are available as a custom product from manufacturers, therefore, additional research and expenditure on the part of DOE is not needed.
- This study and the analyses presented herein are based primarily on a limited number of laboratory compression tests on a single soil type. Additional testing on other potential waste soil types should be performed to more completely determine settlement potential. Minimum and maximum density tests should be performed to indicate the total settlement that can be expected over indefinite periods of time. A well-designed field monitoring program should be performed during the early phases of ERDF operation to directly measure settlements as they develop during waste placement.
- Gas generation from decomposing trash is not expected to be a problem.
- Preliminary results of the groundwater modeling suggests that the exposure associated with the area fill trench configuration will not be significantly different from conventional trenches. Given the uncertainty of the long-term performance of either the area fill or conventional trenches, there is no significant difference between the 2 designs in terms of groundwater contamination

Section 3 presents the criteria associated with mechanical conveying of the waste.

- Waste acceptance criteria based upon minimizing the wear and damage to the conveyor transportation system and the waste processing equipment which facilitates the conveyors operation are listed below:
 - The primary waste material that the ERDF will handle will be soils and overburden material which will be easily accommodated by all components of the conveyor system.
 - Soil material shall be less than 3 feet in diameter (to avoid damage to the "grizzly" and containers)
 - Non-overburden and non-soil wastes from the burial grounds will not be transported by conveyor. The majority (59 percent) is larger than six inches

and it will be a more streamlined operation to transport all burial ground waste by alternate means rather than process all the burial ground waste through the "grizzly" to collect a relatively small percentage of material that can be transported by conveyor. This will require source separation at the remediation sites.

- Processing of organic material from the burial grounds to produce a uniform material blended with inorganic material will require an extensive processing system consisting of either air classifiers or magnets in addition to the shredder. The heavy maintenance requirements of such an elaborate system along with its high capital costs is not warranted for the relatively small quantity of organic material which is anticipated (41 percent of burial ground debris).
- Removing metallic objects from the wastes will provide some reduction in wear of the system, but this benefit is not significant enough to warrant the high costs of preprocessing the material by either milling or crushing in addition to the costs of the magnet.
- Oversized objects from the burial ground and cobbles and boulders contained in soil materials comprise a significant proportion of the wastes (82 percent of burial ground wastes and 18 percent of soils) and must either be reduced to less than 6 inches in diameter so that it can be transported by the conveyor system or be separated from the other waste material and transported by truck into the trench. The simple and inexpensive process of separating out the oversized by use of a "grizzly" is recommended. The oversized material will be placed in a tote bin for hauling to the trench.
- The material larger than 10 mm in diameter must be separated from the material which will pass through the agglomerator. Removal of the material larger than 10 mm in size by use of the vibratory screen is recommended.
- Alternative rail car systems will require special unloading facilities which are substantially more expensive than the current plan for transportation of waste using containers and unloading using simple wheeled container loaders. Additionally, these rail cars will require additional time and expense to decontaminate. Using liners and sacks is not cost effective. Based upon these considerations, the current plan of using removable containers on flat bed rail cars appears to be the best suited for transportation to the ERDF.
- A mechanical handling and conveying system will have sufficient capacity to handle 2 million yd³/yr of CH LLW overburden and soils. To ensure proper operation, large material, demolition debris, mixed LLW, and single-use containers should be source separated and routed directly to the trench. The mechanical handling system will screen material larger than 6 inches in size with a "grizzly". This screened material will be placed in a tote bin for hauling to the trench. Material smaller than 6 inches and larger than 10 mm will be removed by vibrating screens. Material smaller than 10 mm will be agglomerated (for dust control) and combined with the midsized material. The combined waste will be conveyed and placed in the trench. Additional dust control measures will be implemented at the transfer points. The system will operate with minimal staff.

Section 4 discussed decontamination of conveyors and rail cars, black haul of clean material to the remediation sites, and maintenance of equipment.

- The conveyors can be easily decontaminated using water.
- The decontamination of rail cars will be protracted and may be as much as 4 hours per car which will make use of these alternate rail cars impractical. Therefore, it is recommended to continue design based on use of removable containers mounted on flat bed rail cars.
- The use of excess materials from the trench excavation for the daily cover and Hanford Barrier is economical and could save between \$18.61 million and \$12.43 million. In addition, the remaining excess material could be back hauled for use as backfill in the remediated sites. These uses of the excavated material are highly recommended.
- The back haul of the material to the remediated sites must be done in accordance with relevant codes.
- The routine maintenance of the equipment can be easily accomplished during weekends and off-shift working hours.

Section 5 compares truck and conveyor transportation of waste materials, the following is the conclusion of this Section:

- Waste materials should be conveyed by truck from the railhead to the trenches.

Section 6 compares various trench configuration with the following conclusions:

- The conveyor transport is only practical with the area fill trench layout.
- Area fill trench A will utilize 45 percent of the land area of the base case trench. This will provide more buffer area and reduce security fencing and security monitoring.
- Area fill trench A will save \$121 million of the liner cost of the base case trench.
- Area fill trench A will save \$22 million of the excavation cost of the base case trench.
- Area fill trench A will save \$581 million of the Hanford Barrier cost for the base case trench.
- Area fill trench A will save \$2 million of the base case road construction costs and will require one less truck and driver for on-site transfer of containers.
- Area fill trench C will utilize 21 percent of the land area of the base case trench. This will provide more buffer area and reduce security fencing and security monitoring.
- Area fill trench C will save \$202 million of the liner cost of the base case trench.
- Area fill trench C will save over \$22 million of the excavation cost of the base case trench.
- Area fill trench C will save \$776 million of the Hanford Barrier cost for the base case trench.

- Area fill trench C will save \$2 million of the base case road construction costs and will require one less truck and driver for on-site transfer of containers.
- Based on the above, area fill trench configuration C is recommended for implementation and for further discussion with the regulatory agencies.
- Eliminating the requirement for the RCRA liner will save \$296 million of the base case trench liners and \$175 million of the area fill trench A liner. It will also increase the storage volume of the base case by 23 percent and by 4 percent for area fill trench A. This also reduces the required area and the cost of the Hanford Barrier.

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APPENDIX A

TRENCH COST COMPARISONS

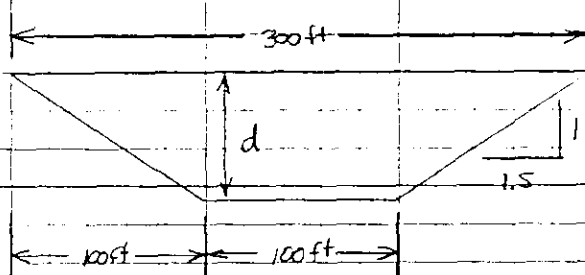
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Unlined Trench Capacity

Assumptions: 300 ft across top - comparable to "Base Case" Trench

100 ft bottom width - required for equipment

1.5H:1V Side slopes - current practice on site



$$d = \frac{100 \text{ ft}}{1.5} = 67 \text{ ft}$$

$$A = 2 \times 100 \times 67 = 13,400 \text{ ft}^2$$

$$\text{Volume per linear foot} = 13,400 \text{ ft}^2 \times 1 \text{ ft} = 13,400 \text{ ft}^3$$

$$= 496 \text{ yd}^3$$

$$\text{Say } 500 \text{ yd}^3/\text{ft}$$

Capacity of base case trench = 250 yd³/ft by similar analysis for 3H:1V side slopes

∴ Unlined trench has 2x capacity of base case trench

Area required will be about 1/2. (assume spacing between trenches, perimeter areas are similar)

Cost of excavation:

Assume average value of 1/2 yd³ (see sheet 11, Appendix E of DOE/RL/12071-15 Rev. 0.)

Golder Associates

SUBJECT Trench Cost Comparisons

Job No. 923-A022

Ref. Megatrench

Made by FSS

Checked AG

Reviewed

Date 8-27-93

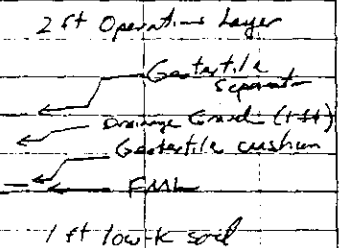
Sheet 2 of 4

Cost = Σ excavation + Liner + Cover (see DOE/RH/2074-15 rev 0 for quantity derivation + unit costs)

	<u>Base Case</u>	<u>Single</u>	<u>Unlined</u>
<u>Excavation:</u>	35,000,000 yd ³	33,000,000 yd ³	30,000,000 yd ³
	x 2 =	x 2 =	x 2 =
	\$70,000,000	\$66,000,000	\$60,000,000

Liner: Double = $\$9.88/\text{yd}^3 \text{ of waste} \times 30,000,000 \text{ yd}^3 = \$296,000,000$

Single: Assume Liner section:



Unit costs: Admix: $\$31.36/\text{yd}^3 \times \frac{1 \text{ yd}^3}{27 \text{ ft}^3} \times \frac{1 \text{ ft}^3}{\text{ft}^2} = \1.16

FML: $\$0.69/\text{ft}^2$ = $\$0.69$

Geotextile Cushion: $0.26/\text{ft}^2$ = 0.26

Drainage Gravel: $\$23.10/\text{yd}^3 \times \frac{1 \text{ yd}^3}{27 \text{ ft}^3} \times \frac{1 \text{ ft}^3}{\text{ft}^2} = \0.86

Geotextile Separator: $0.16/\text{ft}^2$ = 0.16

Operations Layer: $2.69/\text{yd}^3 \times \frac{1 \text{ yd}^3}{27 \text{ ft}^3} \times \frac{2 \text{ ft}^3}{\text{ft}^2} = 0.21$

Total: $3.34/\text{ft}^2$

Golder Associates

SUBJECT Trench Cost Comparison

Job No. 923-A022

Ref. Megatrench

Made by FAS

Checked A.G. 8/27/93

Reviewed

Date 8-27-93

Sheet 3 of 4

Linear Area per Linear foot of trench (assume 2H:1V side slopes):

$$\frac{2 \times 100}{\cos 18.43} + 100 = 310 \text{ ft}$$

$$\therefore \text{Area} = 310 \text{ ft}^2$$

$$\therefore \text{Cost} = \frac{310 \text{ ft}^2}{1 \text{ lin ft}} \times 1.34 \frac{\text{ft}^2}{\text{ft}^2} \times \frac{1 \text{ lin ft}}{260 \text{ yd}^3 \text{ waste}} = 3.98 / \text{yd}^3 \text{ of waste}$$

$$3.98 \times 30,000,000 = \$119,000,000$$

Unlined: liner cost = 0

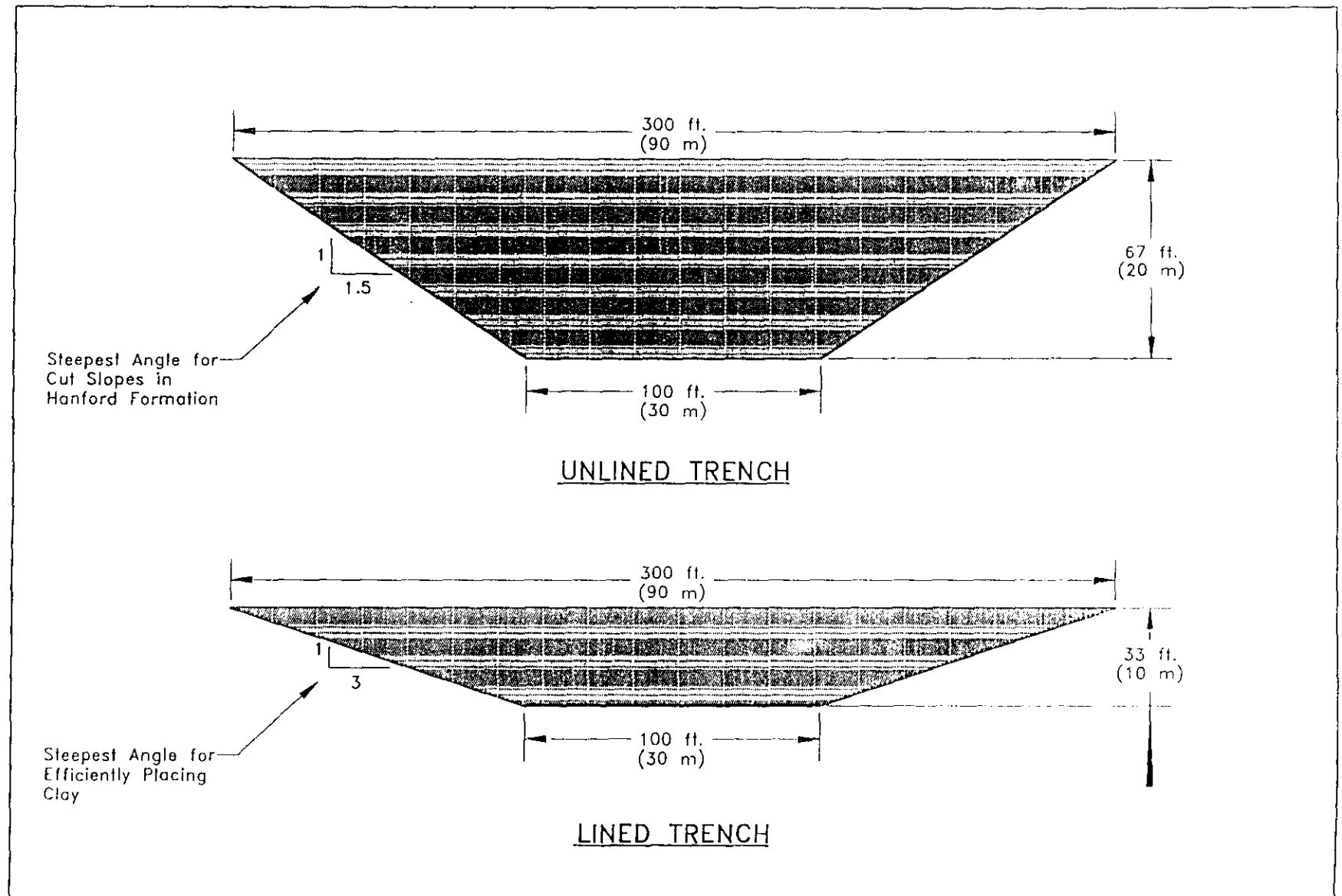
Core Hanford Barrier at $14 \frac{32}{25} / \text{ft}^2$ (see Appendix H)

$$\text{Double Lined + Single Lined: } 1576 \text{ acres} \times 43,560 \text{ ft}^2/\text{acre} \times 14 \frac{32}{25} / \text{ft}^2 = \$1,716,000,000 \quad 983,400,000$$

$$\text{Unlined: } \frac{1}{2} \times 1576 \text{ acres} \times 43,560 \text{ ft}^2/\text{acre} \times 14 \frac{32}{25} / \text{ft}^2 = \$491,700,000$$

<u>Summary</u>	<u>Base Case</u>	<u>Single</u>	<u>Unlined</u>
Excav.	\$70,000,000	\$66,000,000	\$60,000,000
Liner	\$296,000,000	\$119,000,000	0
Core	\$1,716,000,000 983,000,000	\$1,716,000,000 983,000,000	\$491,700,000 858,000,000
Total	\$2,082,000,000 1,349,000,000	\$1,901,000,000 1,168,000,000	\$918,000,000 552,000,000

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Figure 3-3. Cross-Sectional Dimensions for Lined and Unlined Trenches.

Sheet 4 of 4

APPENDIX B

ENVIROCARE OF UTAH, INC. TELECONFERENCE

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PROJECT CONTACT REPORTDATE: 7-21-93PAGE 1 OF 1U.S. CORPS OF ENGINEERS
WALLA WALLA DISTRICTCONTRACT NO. DACW68-92-D-0001
DELIVERY ORDER NO. 22Subject: Incompatible Wastes - Megatrench

Discussion:

Envirocare segregates incompatible wastes by a compacted clay barrier at least 2 feet thick. Same clay as used for their liner system.

JMM PARTY

OTHER PARTY

Project Name: Megatrench
 Employee's Name: Frank S. Shuri
 Employee's Company: Golder Associates Inc
 Date: 7-21-93 Time: 1100

Organization's Name: Envirocare of Utah
 Address: Salt Lake City
 Phone No.: 801-532-1330
 Person's Name: Kent Parker

CALL PLACED BY: JMM ☒OTHER PARTY ☐

DISTRIBUTION:

☐ JMM
☒ File
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APPENDIX C

APPENDIX V TO 40 CFR 264 - EXAMPLES OF POTENTIALLY INCOMPATIBLE WASTE

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store, or dispose of each quantity of hazardous waste received.

1. Storage

- S01 Container (barrel, drum, etc.)
- S02 Tank
- S03 Waste pile
- S04 Surface impoundment
- S05 Other (specify)

2. Treatment

- (a) Thermal Treatment
 - T06 Liquid injection incinerator
 - T07 Rotary kiln incinerator
 - T08 Fluidized bed incinerator
 - T09 Multiple hearth incinerator
 - T10 Infrared furnace incinerator
 - T11 Molten salt destructor
 - T12 Pyrolysis
 - T13 Wet air oxidation
 - T14 Calcination
 - T15 Microwave discharge
 - T16 Cement kiln
 - T17 Lime kiln
 - T18 Other (specify)
- (b) Chemical Treatment
 - T19 Absorption mound
 - T20 Absorption field
 - T21 Chemical fixation
 - T22 Chemical oxidation
 - T23 Chemical precipitation
 - T24 Chemical reduction
 - T25 Chlorination
 - T26 Chlorinolysis
 - T27 Cyanide destruction
 - T28 Degradation
 - T29 Detoxification
 - T30 Ion exchange
 - T31 Neutralization
 - T32 Ozonation
 - T33 Photolysis
 - T34 Other (specify)

(c) Physical Treatment

- (1) Separation of components
 - T35 Centrifugation
 - T36 Clarification
 - T37 Coagulation
 - T38 Decanting
 - T39 Encapsulation
 - T40 Filtration
 - T41 Flocculation
 - T42 Flotation
 - T43 Foaming
 - T44 Sedimentation
 - T45 Thickening
 - T46 Ultrafiltration
 - T47 Other (specify)

(2) Removal of Specific Components

- T48 Absorption-molecular sieve
- T49 Activated carbon
- T50 Blending
- T51 Catalysis
- T52 Crystallization
- T53 Dialysis
- T54 Distillation
- T55 Electrodialysis
- T56 Electrolysis
- T57 Evaporation
- T58 High gradient magnetic separation

- T59 Leaching
- T60 Liquid ion exchange
- T61 Liquid-liquid extraction
- T62 Reverse osmosis
- T63 Solvent recovery
- T64 Stripping
- T65 Sand filter
- T66 Other (specify)
- (d) Biological Treatment
 - T67 Activated sludge
 - T68 Aerobic lagoon
 - T69 Aerobic tank
 - T70 Anaerobic lagoon
 - T71 Composting
 - T72 Septic tank
 - T73 Spray irrigation
 - T74 Thickening filter
 - T75 Trickling filter
 - T76 Waste stabilization pond
 - T77 Other (specify)
 - T78-79 [Reserved]
- 3. Disposal
 - D80 Underground injection
 - D81 Landfill
 - D82 Land treatment
 - D83 Ocean disposal
 - D84 Surface impoundment (to be closed as a landfill)
 - D85 Other (specify)

APPENDICES II-III TO PART 264— [RESERVED]

APPENDIX IV TO PART 264—COCHRAN'S APPROXIMATION TO THE BEHRENS- FISHER STUDENTS' T-TEST

Using all the available background data (n_b readings), calculate the background mean (\bar{X}_b) and background variance (s_b^2). For the single monitoring well under investigation (n_m reading), calculate the monitoring mean (\bar{X}_m) and monitoring variance (s_m^2).

For any set of data (X_1, X_2, \dots, X_n) the mean is calculated by:

$$\bar{X} = \frac{X_1 + X_2 + \dots + X_n}{n}$$

and the variance is calculated by:

$$s^2 = \frac{(X_1 - \bar{X})^2 + (X_2 - \bar{X})^2 + \dots + (X_n - \bar{X})^2}{n - 1}$$

where "n" denotes the number of observations in the set of data.

The t-test uses these data summary measures to calculate a t-statistic (t^*) and a comparison t-statistic (t_c). The t^* value is com-

pared to the t_c value and a conclusion reached as to whether there has been a statistically significant change in any indicator parameter.

The t-statistic for all parameters except pH and similar monitoring parameters is:

$$t^* = \frac{\bar{X}_m - \bar{X}_b}{\sqrt{\frac{s_m^2}{n_m} + \frac{s_b^2}{n_b}}}$$

If the value of this t-statistic is negative then there is no significant difference between the monitoring data and background data. It should be noted that significantly small negative values may be indicative of a failure of the assumption made for test validity or errors have been made in collecting the background data.

The t-statistic (t_c), against which t^* will be compared, necessitates finding t_b and t_m from standard (one-tailed) tables where, t_b = t-tables with ($n_b - 1$) degrees of freedom, at the 0.05 level of significance, t_m = t-tables with ($n_m - 1$) degrees of freedom, at the 0.05 level of significance.

Finally, the special weightings W_b and W_m are defined as:

$$W_b = \frac{s_b^2}{n_b} \quad \text{and} \quad W_m = \frac{s_m^2}{n_m}$$

and so the comparison t-statistic is:

$$t_c = \frac{W_b t_b + W_m t_m}{W_b + W_m}$$

The t-statistic (t^*) is now compared with the comparison t-statistic (t_c) using the following decision-rule:

If t^* is equal to or larger than t_c , then conclude that there most likely has been a significant increase in this specific parameter.

If t^* is less than t_c , then conclude that most likely there has not been a change in this specific parameter.

The t-statistic for testing pH and similar monitoring parameters is constructed in the same manner as previously described except the negative sign (if any) is discarded and the caveat concerning the negative value is ignored. The standard (two-tailed) tables are used in the construction t_c for pH and similar monitoring parameters.

If t^* is equal to or larger than t_c , then conclude that there most likely has been a significant increase (if the initial t^* had been negative, this would imply a significant de-

crease). If t^* is less than t_c , then conclude that there most likely has been no change.

A further discussion of the test may be found in *Statistical Methods* (6th Edition, Section 4.14) by G. W. Snedecor and W. G. Cochran, or *Principles and Procedures of Statistics* (1st Edition, Section 5.8) by R. G. D. Steel and J. H. Torrie.

STANDARD T-TABLES 0.05 LEVEL OF
SIGNIFICANCE

Degrees of freedom	t-values (one-tail)	t-values (two-tail)
1	6.314	12.706
2	2.920	4.303
3	2.353	3.182
4	2.132	2.776
5	2.015	2.571
6	1.943	2.447
7	1.895	2.365
8	1.860	2.306
9	1.833	2.262
10	1.812	2.228
11	1.796	2.201
12	1.782	2.179
13	1.771	2.160
14	1.761	2.145
15	1.753	2.131
16	1.746	2.120
17	1.740	2.110
18	1.734	2.101
19	1.729	2.093
20	1.725	2.086
21	1.721	2.080
22	1.717	2.074
23	1.714	2.069
24	1.711	2.064
25	1.708	2.060
30	1.697	2.042
40	1.684	2.021

Adapted from Table III of "Statistical Tables for Biological, Agricultural, and Medical Research" (1947, R. A. Fisher and F. Yates)

[47 FR 32367, July 26, 1982]

APPENDIX V TO PART 264—EXAMPLES OF POTENTIALLY INCOMPATIBLE WASTE

Many hazardous wastes, when mixed with other waste or materials at a hazardous waste facility, can produce effects which are harmful to human health and the environment, such as (1) heat or pressure, (2) fire or explosion, (3) violent reaction, (4) toxic dusts, mists, fumes, or gases, or (5) flammable fumes or gases.

Below are examples of potentially incompatible wastes, waste components, and materials, along with the harmful consequences which result from mixing materials in one group with materials in another group. The list is intended as a guide to owners or operators of treatment, storage, and disposal facilities, and to enforcement and permit granting officials, to indicate the need for

special precautions when managing these potentially incompatible waste materials or components.

This list is not intended to be exhaustive. An owner or operator must, as the regulations require, adequately analyze his wastes so that he can avoid creating uncontrolled substances or reactions of the type listed below, whether they are listed below or not.

It is possible for potentially incompatible wastes to be mixed in a way that precludes a reaction (e.g., adding acid to water rather than water to acid) or that neutralizes them (e.g., a strong acid mixed with a strong base), or that controls substances produced (e.g., by generating flammable gases in a closed tank equipped so that ignition cannot occur, and burning the gases in an incinerator).

In the lists below, the mixing of a Group A material with a Group B material may have the potential consequence as noted.

GROUP 1-A

Acetylene sludge
Alkaline caustic liquids
Alkaline cleaner
Alkaline corrosive liquids
Alkaline corrosive battery fluid
Caustic wastewater
Lime sludge and other corrosive alkalies
Lime wastewater
Lime and water
Spent caustic

GROUP 1-B

Acid sludge
Acid and water
Battery acid
Chemical cleaners
Electrolyte, acid
Etching acid liquid or solvent
Pickling liquor and other corrosive acids
Spent acid
Spent mixed acid
Spent sulfuric acid

Potential consequences: Heat generation; violent reaction.

GROUP 2-A

Aluminum
Beryllium
Calcium
Lithium
Magnesium
Potassium
Sodium
Zinc powder
Other reactive metals and metal hydrides

GROUP 2-B

Any waste in Group 1-A or 1-B

Potential consequences: Fire or explosion; generation of flammable hydrogen gas.

Alcohols
Water

GROUP 3-A

GROUP 3-B

Any concentrated waste in Groups 1-A or 1-B

Calcium
Lithium
Metal hydrides
Potassium
SO₂Cl₂, SOCl₂, PCl₃, CH₃SiCl₃,
Other water-reactive waste

Potential consequences: Fire, explosion, or heat generation; generation of flammable or toxic gases.

GROUP 4-A

Alcohols
Aldehydes
Halogenated hydrocarbons
Nitrated hydrocarbons
Unsaturated hydrocarbons
Other reactive organic compounds and solvents

GROUP 4-B

Concentrated Group 1-A or 1-B wastes
Group 2-A wastes

Potential consequences: Fire, explosion, or violent reaction.

GROUP 5-A

Spent cyanide and sulfide solutions

GROUP 5-B

Group 1-B wastes

Potential consequences: Generation of toxic hydrogen cyanide or hydrogen sulfide gas.

GROUP 6-A

Chlorates
Chlorine
Chlorites
Chromic acid
Hypochlorites
Nitrates
Nitric acid, fuming
Perchlorates
Permanganates
Peroxides
Other strong oxidizers

GROUP 6-B

Acetic acid and other organic acids
Concentrated mineral acids
Group 2-A wastes
Group 4-A wastes

Other flammable and combustible wastes

Potential consequences: Fire, explosion, or violent reaction.

Environmental Protection Agency

Source: "Law, Regulations, and Guidelines for Handling of Hazardous Waste." California Department of Health, February 1975.

[46 FR 2872, Jan. 12, 1981]

APPENDIX VI TO PART 264--POLITICAL JURISDICTIONS¹ IN WHICH COMPLIANCE WITH § 264.18(a) MUST BE DEMONSTRATED

ALASKA

Aleutian Islands	Kodiak
Anchorage	Lynn Canal-Icy Straits
Bethel	Palmer-Wasilla-Talkeena
Bristol Bay	Seward
Cordova-Valdez	Sitka
Fairbanks-Fort Yukon	Wade Hampton
Juneau	Wrangell Petersburg
Kenai-Cook Inlet	Yukon-Kuskokwim
Ketchikan-Prince of Wales	

ARIZONA

Cochise	Greenlee
Graham	Yuma

CALIFORNIA

All

COLORADO

Archuleta	Mineral
Conejos	Rio Grande
Hinsdale	Saguache

HAWAII

Hawaii

IDAHO

Bannock	Franklin
Bear Lake	Fremont
Bingham	Jefferson
Bonneville	Madison
Caribou	Oneida
Cassia	Power
Clark	Teton

MONTANA

Beaverhead	Granite
Broadwater	Jefferson
Cascade	Lake
Deer Lodge	Lewis and Clark
Flathead	Madison
Gallatin	Meagher

Missoula
Park
Powell
Sanders
Silver Bow

Stillwater
Sweet Grass
Teton
Wheatland

NEVADA

All

NEW MEXICO

Bernalillo	Sante Fe
Catron	Sierra
Grant	Socorro
Hidalgo	Taos
Los Alamos	Torrance
Rio Arriba	Valencia
Sandoval	

UTAH

Beaver	Plute
Box Elder	Rich
Cache	Salt Lake
Carbon	Sanpete
Davis	Sevier
Duchesne	Summit
Emery	Tooele
Garfield	Utah
Iron	Wasatch
Juab	Washington
Millard	Wayne
Morgan	Weber

WASHINGTON

Chelan	Mason
Clallam	Okanogan
Clark	Pacific
Cowlitz	Pierce
Douglas	San Juan Islands
Ferry	Skagit
Grant	Skamania
Grays Harbor	Snohomish
Jefferson	Thurston
King	Wahkiakum
Kitsap	Whatcom
Kittitas	Yakima
Lewis	

WYOMING

Fremont	Teton
Lincoln	Uinta
Park	Yellowstone National Park
Sublette	

[46 FR 57285, Nov. 23, 1981; 47 FR 953, Jan. 8, 1982]

APPENDICES VII-VIII TO PART 264 -- (RESERVED)

¹These include counties, city-county consolidations, and independent cities. In the case of Alaska, the political jurisdictions are

election districts, and, in the case of Hawaii, the political jurisdiction listed is the island of Hawaii.

APPENDIX D

**IMMEDIATE SETTLEMENT ANALYSIS
FOR CONTAINERIZED WASTE**

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APPENDIX D

IMMEDIATE SETTLEMENT ANALYSIS FOR CONTAINERIZED WASTES

1.0 REQUIREMENT

What minimum density is required for containerized soil to avoid settlement of the soil column following corrosion of the container and transference of the overburden load to the soil in the container?

2.0 PLAN

Immediate settlements associated with the loading of the soil within the container can be computed using the following equation:

$$S_i = \frac{\Delta\sigma'_v H_0}{D}$$

where:

- S_i = immediate settlement
- σ'_v = load from overlying waste and Hanford Barrier (increase in vertical effective stress)
- H_0 = height of container or height of soil element considered
- D = one-dimensional modulus

The modulus values used can be correlated with densities and this allows a density to settlement relationship to be established. For this study, the following density relations are assumed:

Density Description	Units Weight (pounds per cubic foot) (lbs/ft ³)	One-Dimensional Modulus (pounds per square foot) (lbs/ft ²)
Loose	90-115 ^a	200,000-3,000,000 ^c
	105 ^b	220,687 ^b
Dense	110-140	1,000,000-4,000,000 ^c
	128 ^b	1,205,000 ^b

^aTypical range of values for sands and gravels (Bowles 1988).

^bResults from lab testing of single soil sample (see Section 2.3.1.4).

^cLow end of range of values typical for sands and high end of range of values typical for gravels (Bowles 1988).

Differential settlement of the containerized soil relative to the adjacent soil is one settlement consideration. The second consideration is the total settlement observed at the top of the waste/bottom of the Hanford Barrier.

2.1 IMMEDIATE SETTLEMENT AT TOP OF CONTAINER

The immediate settlement at the top of the container was computed to determine the amount of differential settlement relative to the adjacent soil.

The container or element of soil being compressed was assumed to be four feet in thickness and the overburden weight compressing it was computed for two conditions, for a 33-foot deep trench and for a 50-foot deep trench. In all cases, the weight of the Hanford Barrier was included and assumed to be 15 feet in thickness. Unit weights for the waste material above the container and for the barrier were assumed to be 128 lbs/ft³. The computed compression of the containerized waste is insignificant for all cases, especially when compared to adjacent compression (which if the waste material adjacent to the container is compacted to densities which produce high modulus values of 4 million lbs/ft² the differential settlement is insignificant).

2.2. IMMEDIATE SETTLEMENT AT TOP OF WASTE/BOTTOM OF BARRIER

The settlement at the top of the waste or bottom of the asphalt layer portion of the Hanford Barrier was computed by dividing the waste column in the trench into layers and computing the compression of each layer. The overburden weight compressing individual layers was computed based upon the height of waste measured from the mid point of the layer to the top of the waste plus the weight of the barrier (assumed to be 15 feet in thickness). The compression of each layers was summed to determine the total settlement that would be observed at the top of the waste for trenches 33 feet in depth and for 50 feet in depth. This computation was performed for loose and dense soils (assumed containerized waste and waste column consisted of same density material). The results are shown in the following tables. In all cases the computed settlement was minimal.

3.0 CONCLUSIONS

None of the modulus/densities considered in this analysis resulted in excessive settlement or differential settlement. It is recommended that waste material be placed into containers with a minimum density of 105 lbs/ft³. This should be easily achieved.

Although immediate settlement associated with the anticipated Hanford soils modulus values is not anticipated to be a problem, potential settlement of the low density material when subjected to vibration (such as an earthquake) could be a problem as indicated in Appendix E, Settlement Calculations, Section 3.0, "Laboratory Testing Program". It is assumed that the potential for settlement of the containerized waste due to vibrations is reduced because of the vibrations occurring during transportation of the containers. Once the containers arrive on-site, the contents will be inspected and void spaces larger than two inches will be grouted. It is assumed that the asphalt layer of the Hanford Barrier can accommodate a two-inch differential settlement.

IMMEDIATE SETTLEMENT - MEASURED AT TOP OF CONTAINER

Unit Weight (lbs/ft ³)	Density	Young Modulus (lbs/ft ³)	Assume 33-foot Trench		Assume 50-foot Trench	
			Overburden Pressure (lbs/ft ³)	Computed Settlement (feet)	Overburden Pressure (lbs/ft ³)	Computed Settlement (feet)
105	Loose	200,000	5,632	0.1126	7,808	0.1562
105	Loose	3,000,000	5,632	0.0075	7,808	0.0104
128	Dense	1,000,000	5,632	0.0225	7,808	0.0312
128	Dense	4,000,000	5,632	0.0056	7,808	0.0078

IMMEDIATE SETTLEMENT - MEASURED AT SURFACE OF COVER
for Loose Soil (Modulus = 200,000 lbs/ft³, unit weight - 105 lbs/ft²)

Layer Depth from trench top (feet)	Layer Height (feet)	Depth to Mid Layer from top cover (feet)	Overburden Pressure Mid Layer (lbs/ft ³)	Computed Compression (for layer) (feet)	Summation Compression (feet)	Total Settlement at Surface (feet)
0-10	10	20	2,100	0.1050	0.1050	0.55 33' Trench
10-20	10	30	3,150	0.1575	0.2625	
20-20	10	40	4,200	0.2100	0.4725	
30-33	3	46.5	4,883	0.0732	0.5457	
33-40	7	51.5	5,408	0.1893	0.7450	1.05 50' Trench
40-50	10	60	6,300	0.3150	1.0500	

IMMEDIATE SETTLEMENT - MEASURED AT SURFACE OF COVER
for Loose Soil (Modulus = 3,000,000 lbs/ft³, unit weight - 105 lbs/ft²)

Layer Depth from trench top (feet)	Layer Height (feet)	Depth to Mid Layer from top cover (feet)	Overburden Pressure Mid Layer (lbs/ft ³)	Computed Compression (for layer) (feet)	Summation Compression (feet)	Total Settlement at Surface (feet)
0-10	10	20	2,100	0.0070	0.0070	0.04 33' Trench
10-20	10	30	3,150	0.0105	0.0175	
20-20	10	40	4,200	0.0140	0.0315	
30-33	3	46.5	4,883	0.0049	0.0364	
33-40	7	51.5	5,408	0.0126	0.0490	0.07 50' Trench
40-50	10	60	6,300	0.0210	0.0700	

IMMEDIATE SETTLEMENT - MEASURED AT SURFACE OF COVER for Loose Soil (Modulus = 1,000,000 lbs/ft ³ , unit weight - 128 lbs/ft ²)						
Layer Depth from trench top (feet)	Layer Height (feet)	Depth to Mid Layer from top cover (feet)	Overburden Pressure Mid Layer (lbs/ft ³)	Computed Compression (for layer) (feet)	Summation Compression (feet)	Total Settlement at Surface (feet)
0-10	10	20	2,560	0.0256	0.0256	0.13 33' Trench
10-20	10	30	3,840	0.0384	0.0640	
20-20	10	40	5,120	0.0512	0.1152	
30-33	3	46.5	5,952	0.0179	0.1331	
33-40	7	51.5	6,592	0.0461	0.1792	.026 50' Trench
40-50	10	60	7,680	0.0768	0.2560	

IMMEDIATE SETTLEMENT - MEASURED AT SURFACE OF COVER for Loose Soil (Modulus = 4,000,000 lbs/ft ³ , unit weight - 128 lbs/ft ²)						
Layer Depth from trench top (feet)	Layer Height (feet)	Depth to Mid Layer from top cover (feet)	Overburden Pressure Mid Layer (lbs/ft ³)	Computed Compression (for layer) (feet)	Summation Compression (feet)	Total Settlement at Surface (feet)
0-10	10	20	2,560	0.0064	0.0064	0.03 33' Trench
10-20	10	30	3,840	0.0096	0.0160	
20-20	10	40	5,120	0.0128	0.0288	
30-33	3	46.5	5,952	0.0045	0.0333	
33-40	7	51.5	6,592	0.0115	0.0448	0.06 50' Trench
40-50	10	60	7,680	0.0192	0.0640	

APPENDIX E

SETTLEMENT CALCULATIONS

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APPENDIX E

1.0 WASTE TYPES AND SETTLEMENT POTENTIAL

The wastes to be placed in the Environmental Restoration Disposal Facility (ERDF) will be predominantly contaminated granular soils (sands and gravels). Assuming that Resource Conservation and Recovery Act (RCRA), Land Disposal Restrictions (LDRs) are enforced, disposal of organic materials, free liquids, or unstabilized toxic metals in the landfill will be prohibited (see Section 2.1). In addition, compactable wastes (such as drums or pipes) will be volume reduced at the remediation sites (Moore 1993). These waste restrictions and processing methods will eliminate waste forms that are likely to cause large settlements.

It is expected that the waste materials will be mainly well-graded granular soils. However, these soils may vary from fine sands and soil washing residue to coarse gravels and cobbles. Specimens of sandy gravel were obtained for the laboratory testing program discussed below; however, this sample may not encompass the full range of waste soils to be disposed. Only one sample was tested as the intent was to confirm textbook compaction values.

2.0 SETTLEMENT COMPONENTS

Waste soils will be disposed in relatively wide, shallow trenches at the ERSDF. Consequently, one-dimensional theory is well-suited for settlement analysis. In general, total settlement of a soil stratum, S_T , is considered as the sum of the immediate settlement, S_i , the consolidation settlement, S_c , and the secondary compression (or creep) settlement, S_s (Holtz and Kovacs 1981):

$$S_T = S_i + S_c + S_s \quad (1)$$

2.1 IMMEDIATE SETTLEMENT

Immediate settlement is time-independent settlement that occurs simultaneously with any increase in effective stress from overlying material. For the ERSDF site, immediate settlement will take place as the waste soils and Barrier are placed. Immediate settlements can be estimated using a one-dimensional settlement equation (Holtz and Kovacs, 1981):

$$S_i = \frac{\Delta\sigma'_v H_0}{D} \quad (2)$$

where: $\Delta\sigma'_v$ = increase in vertical effective stress
 H_0 = initial thickness of compressible stratum
 D = one-dimensional constrained modulus ($\Delta\sigma'_v / \Delta e$)
 e = vertical strain

2.2 CONSOLIDATION SETTLEMENT

Consolidation settlement is time-dependent settlement that occurs as a result of the dissipation of excess pore pressure within a soil stratum. Since the waste soils will be primarily unsaturated coarse granular materials, consolidation settlement is not expected to occur at the ERSDF site. Unsaturated coarse granular materials will settle over time from secondary compression (see next paragraph).

2.3 SECONDARY COMPRESSION SETTLEMENT

Secondary compression settlement is ongoing creep that results from the time-dependent rearrangement of soil particles under constant effective stress conditions. Although granular soils show significantly less creep effects than do clays, creep settlement can be important over the long term, especially for loose sands under high stress conditions. Schmertmann (1970) recommends the following equation for calculation of secondary compression of granular soils:

$$S_s = (S_i + S_c) [1 + 0.2 \log (\frac{t}{0.1})] \quad (3)$$

where: t = time in years

A number of authors have reported a similar semi-logarithmic dependency for time-settlement of granular soils under cyclic loading conditions. For long-term cyclic loading of clean sands, (Holzlochner 1977) suggested a logarithmic relationship between settlement and time. The settlements observed by (Brumund and Leonards, 1973) tended to stop entirely at 105 cycles, whereas the tests conducted by (Tschebotarioff 1953) never reached a static equilibrium settlement condition.

A logarithmic relationship between settlement and time may be inappropriate for design of the ERSDF because of the extremely long life span of the facility. Settlement will be essentially limited by the minimum void ratio of the granular fill. Taking this fact into consideration, the relative density of the fill becomes a critical factor in computing the maximum settlement that may occur.

3.0 LABORATORY TESTING PROGRAM

Settlement characteristics of Hanford granular soils were determined in the Geotechnical Laboratory of Golder Associates, Inc., Redmond, Washington office. One-dimensional compression tests were performed on a well-graded sandy gravel (GW) as classified by the Unified Soil Classification System. This granular soil was prepared by first mixing three soil samples taken from gravel pits located between the 200 East Area and 200 West Area at Hanford (COE 1993a). Particles with diameters larger than 1.5 inches were then removed by sieving to avoid particle binding within the 6-inch inner diameter (ID) sample mold. This oversize fraction accounted for approximately 30 percent of the total original soil sample. The compression tests described below were performed on the remaining 70 percent finer fraction (less than 1.5 inches). This fraction is composed of 72 percent gravel, 26 percent sand, and 2 percent fines. Its grain size distribution is shown in Figure E-1. While this sample is considered representative of one type of bulk soil that may be placed in the ERSDF, other types of soil may also be disposed of in the trenches. Testing a full range of potential soil types was beyond the scope of this study, but should be performed prior to finalizing trench operations and designing the closure cover.

The objective of the laboratory testing program was to measure the one-dimensional constrained modulus, D , under various density and water content conditions. Recall that D is defined as:

$$D = \frac{\Delta\sigma'_v}{\Delta e} \quad (4)$$

3.2 TESTING

Three one-dimensional static compression tests were conducted on the GW using a 6-inch ID California Bearing Ratio (CBR) mold. The following table describes the main features of these tests:

Test	Initial Water Content	Initial Density	Maximum Load (Pounds per square foot) (lb/ft ²)	Figures
1	4.5%	Loose	13,000 lb/ft ²	2-3, 2-4
2	Dry	Dense	13,000 lb/ft ²	2-5, 2-6
3	Dry	Loose	13,000 lb/ft ²	2-7, 2-8

Initially "loose" specimens were prepared by pouring the soil into the mold from a height of 2 feet. This condition represents soil that is placed with little or no compaction, by methods such as a conveyor system or end-dumping from trucks. Initially "dense" specimens were prepared by first pouring the specimen loosely and then compacting the soil under a surcharge of 285 lb/ft² by tapping the sides of the mold with a hammer. This condition is compacted after placement by a vibrating roller or similar equipment. Each specimen was loaded to 13,000 lb/ft². This value was selected to encompass the loading that will be expected from waste in the deepest megatrench (70 feet) plus the weight of the Hanford Barrier (15 feet). Each sample was then unloaded and reloaded 2 more times to the same stress level to evaluate the general characteristics of previously loaded soil (e.g., elastic versus inelastic behavior). For each load cycle, the stress was held constant for 15 minutes at 13,000 lb/ft² to measure the creep tendency of the material. During some tests, the samples were flooded with water to simulate the effects of resaturation of the waste soil at some time in the future.

3.2.1 Test 1

Test 1 was conducted on a loose specimen at an initial water content of 4.5 percent. Figure E-2 shows the stress-strain curves for test 1. The specimen reached 3.5 percent strain during the first load cycle, and strain increased marginally with each successive load cycle. The tangent constrained modulus D at the beginning of loading is 221,000 lb/ft². At the 5,000 lb/ft² stress level, D is 400,000 lb/ft², and at 12,000 lb/ft², D is 650,000 lb/ft². Little rebound occurred upon unloading, and a permanent strain of 3.2 percent remained after the first loading cycle. During the next two reloading cycles, the constrained modulus was much higher at approximately 3,700,000 lb/ft². Figure E-3 shows the creep curve at the 13,000 lb/ft² stress level for the first load cycle. Strain rate decreased rapidly from 0.031 percent per minute (per/min) to 0.00267 per/min over the 15 minutes of elapsed creep. Figure E-2 indicates that the magnitude of creep settlement decreased for each successive loading cycle at the 13,000 lb/ft² stress level.

3.2.2 Test 2

Test 2 was conducted on a dry densified specimen of the GW. During the initial densification procedure, the loose soil underwent a settlement of 9.5 percent to reach a dense condition. The corresponding unit weights were 116.1 pounds per cubic foot (lb/ft^3) and 128.2 lb/ft^3 , respectively. These values should not necessarily be considered as the minimum and maximum unit weights, but probably represent only a portion of the possible density range. Figure E-4 shows the stress-strain curves for test 2. Loading cycles were the same as for test 1 except for the last cycle, which will be discussed below. For the first loading cycle, the constrained modulus D was initially 1,200,000 lb/ft^2 . It then increased to 2,200,000 lb/ft^2 at 5,000 lb/ft^2 stress, and 3,000,000 lb/ft^2 at 12,000 lb/ft^2 stress. For reloading, D increased to approximately 4,000,000 lb/ft^2 .

At 13,000 lb/ft^2 for the third loading cycle of test 2, the following procedure was used: 1) the sample was allowed to creep for 15 minutes, 2) the soil was wetted under drained conditions and allowed to creep for 15 minutes, and 3) the sides of the container were tapped with a mallet and another 15 minutes of creep was allowed. Figure E-5 shows the time-settlement plot for this 45 minute period of constant effective stress. When the specimen was flooded, a settlement of 0.027 percent settlement occurred. An additional 0.058 percent settlement occurred when the mold was tapped with a hammer. This clearly indicates that, even starting from an initially dense condition, the granular specimen showed significant additional settlement coincident with flooding or vibration.

3.2.3 Test 3

Test 3 was conducted on the dry GW in an initially loose condition. Similar to test 1, the specimen was prepared by pouring soil into the CBR mold. The loading procedure was identical to test 2 except that the flooding and tapping events were done at the 13,000 lb/ft^2 level of the first load cycle. Figure E-6 shows the stress-strain curves for test 3. For the first loading cycle, the constrained modulus D was initially 256,000 lb/ft^2 . D then increased to 700,000 lb/ft^2 at 5,000 lb/ft^2 stress, and to 1,200,000 lb/ft^2 at 13,000 lb/ft^2 stress. For reloading, D increased to approximately 3,500,000 lb/ft^2 . Figure E-7 shows the time-settlement curve for wetting and tapping segments for the first load cycle. When the soil was wetted, it rapidly underwent 0.5 percent strain. As the mold was tapped, an additional 0.1 percent strain occurred. This extra settlement resulting from vibration and wetting is considerably less than the 9.5 percent settlement observed when specimen 2 was initially densified. The reason for this smaller value is that insufficient energy was applied to completely disrupt the soil structure at the 13,000 lb/ft^2 stress level.

3.3 TEST RESULTS

The following table summarizes the results of the laboratory testing program:

Test	Initial Loading D ($\times 10^5 \text{ lb/ft}^2$)	Reloading D ($\times 10^5 \text{ lb/ft}^2$)	Strain from Tapping	Strain from Wetting
1	2.2 to 6.5	37	-	-
2	12 to 30	40	0.06%	0.03%
3	2.6 to 12	35	0.10%	0.50%

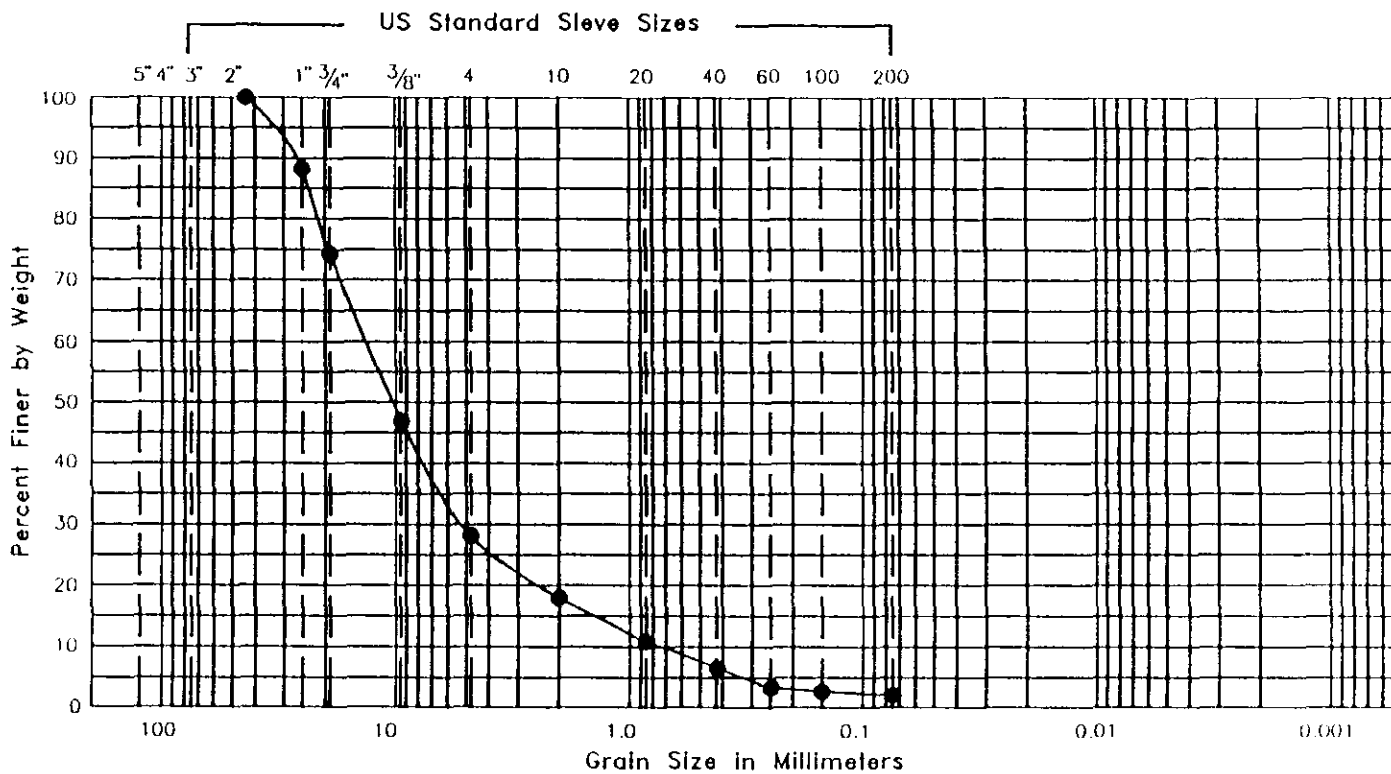
The laboratory test results clearly indicate that constrained modulus is stress-dependent. The loose specimens (tests 1 and 3) have significantly lower D than the dense specimen (test 2)

during the first loading cycle. However, during subsequent reloading cycles, the loose specimens show only slightly reduced D values. The data also suggest that an initially moist loose specimen (test 1) is more compressible than an initially dry loose specimen (test 3). The loose specimens also show significant additional strains resulting from flooding and vibration at the 13,000 lb/ft² stress level, whereas the dense specimen showed only small additional settlement as a result of these procedures.

4.0 COMPARISONS OF DATA

Constrained modulus values taken from the literature were compared with those determined experimentally. Scott (1981) states that a value of D for dense sand under typical foundation pressures is 6.5×10^6 lb/ft². Kezdi (1975) lists typical values for constrained modulus as 2.2×10^5 to 5.0×10^5 lb/ft² for loose sand, 1.0×10^6 to 1.7×10^6 lb/ft² for dense sand, and 2.0×10^6 to 4.0×10^6 lb/ft² for dense sand and gravel. The experimentally determined values for the Hanford GW soil are in agreement with these general guidelines.

Figure E-1. Composite Loading Sample Grain Size Distribution.



Cobbles	Gravel		Sand			Finos
	Coarse	Fine	Coarse	Medium	Fine	Silt or Clay

Sample ID	Elev. or Depth	W _n	W _L	W _p	I _p	Description
Composite 1, 3, and 5						Yellowish gray (5 Y 7/2), c-f GRAVEL, some c-f sand, trace silt (GW).

Figure E-2. Loading Curve - Loose Sample, 4.5% Water Content.

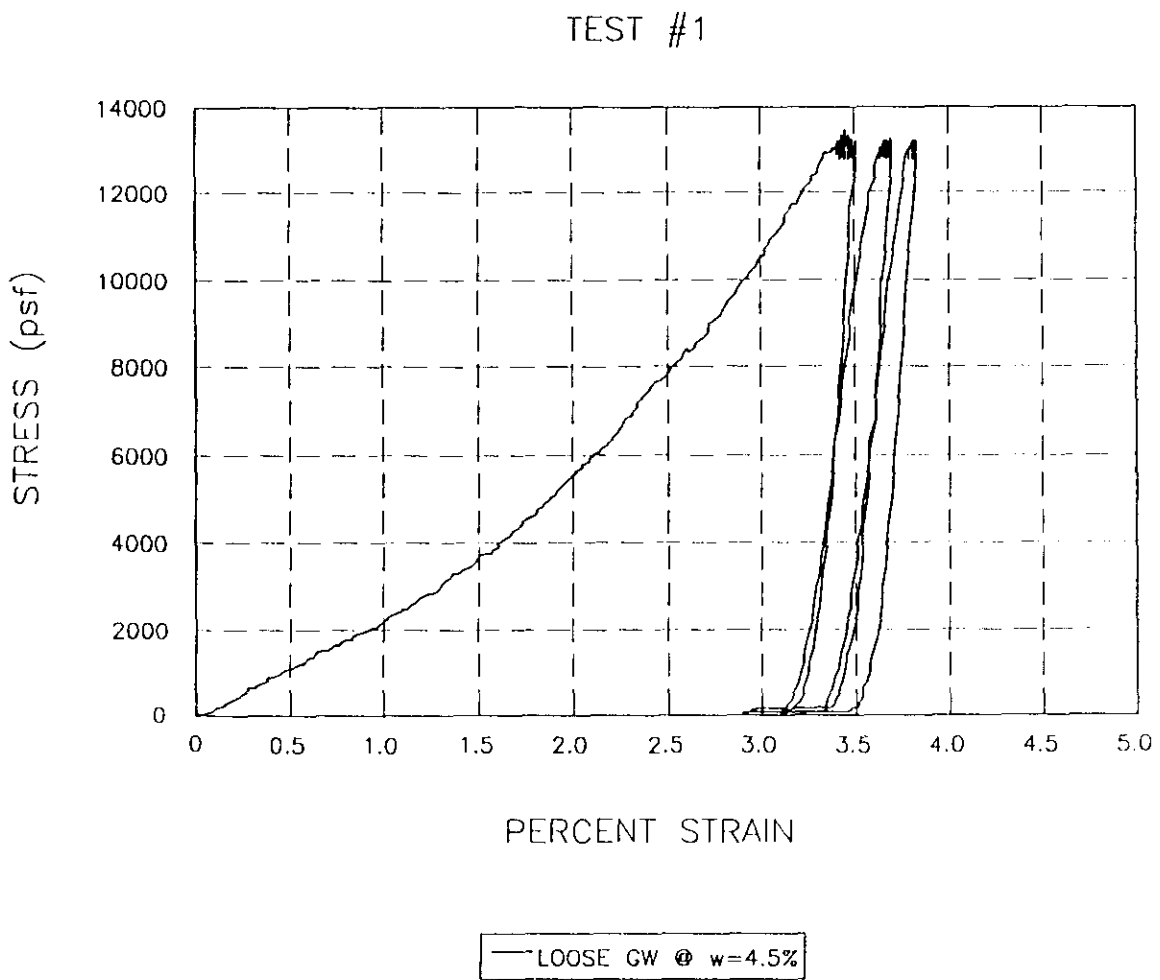


Figure E-3. Creep Curve - Loose Sample, 4.5% Water Content.

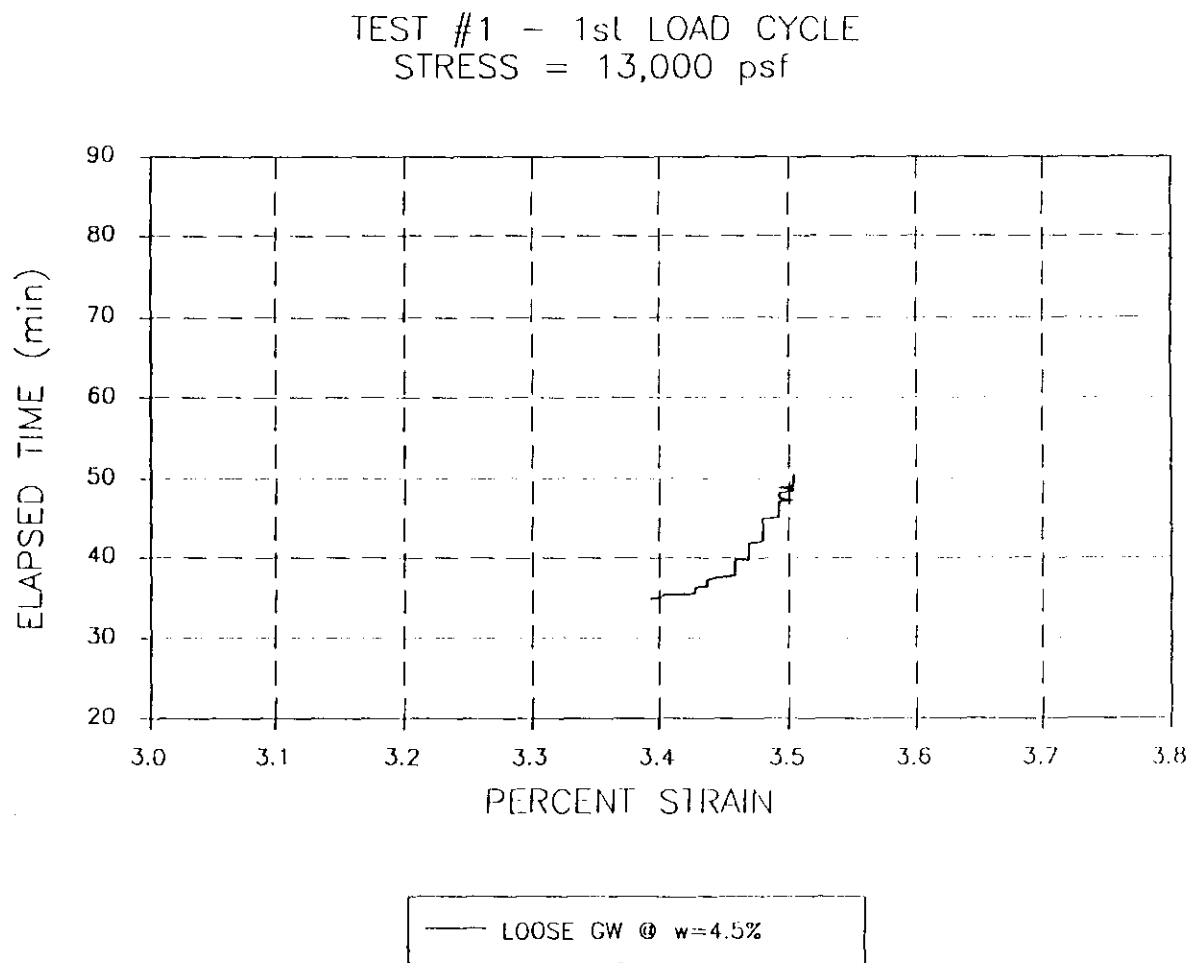


Figure E-4. Loading Curve - Dense Sample, Dry.

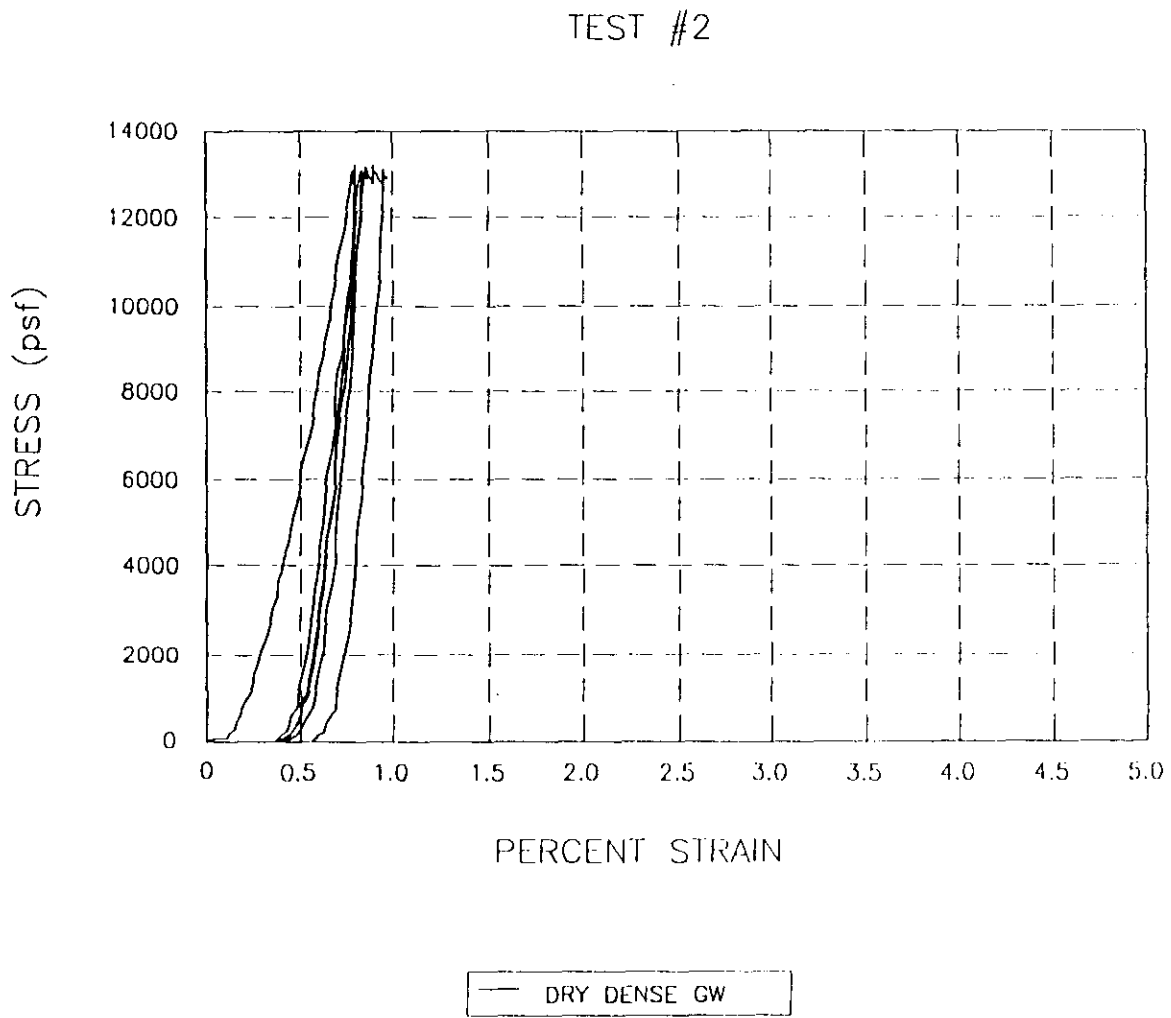


Figure E-5. Creep Curve - Dense Sample, Dry.

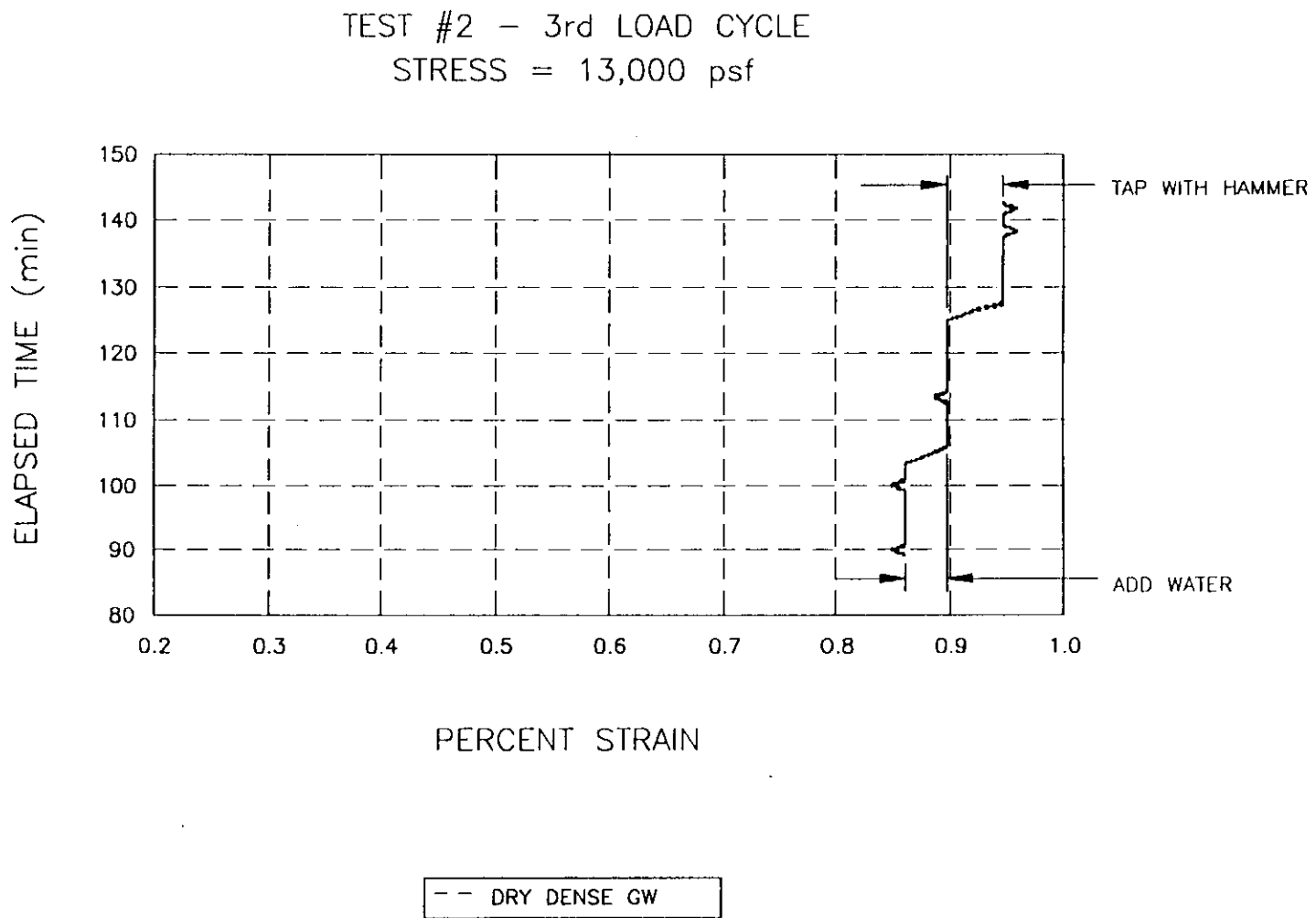


Figure E-6. Loading Curve - Loose Sample, Dry.

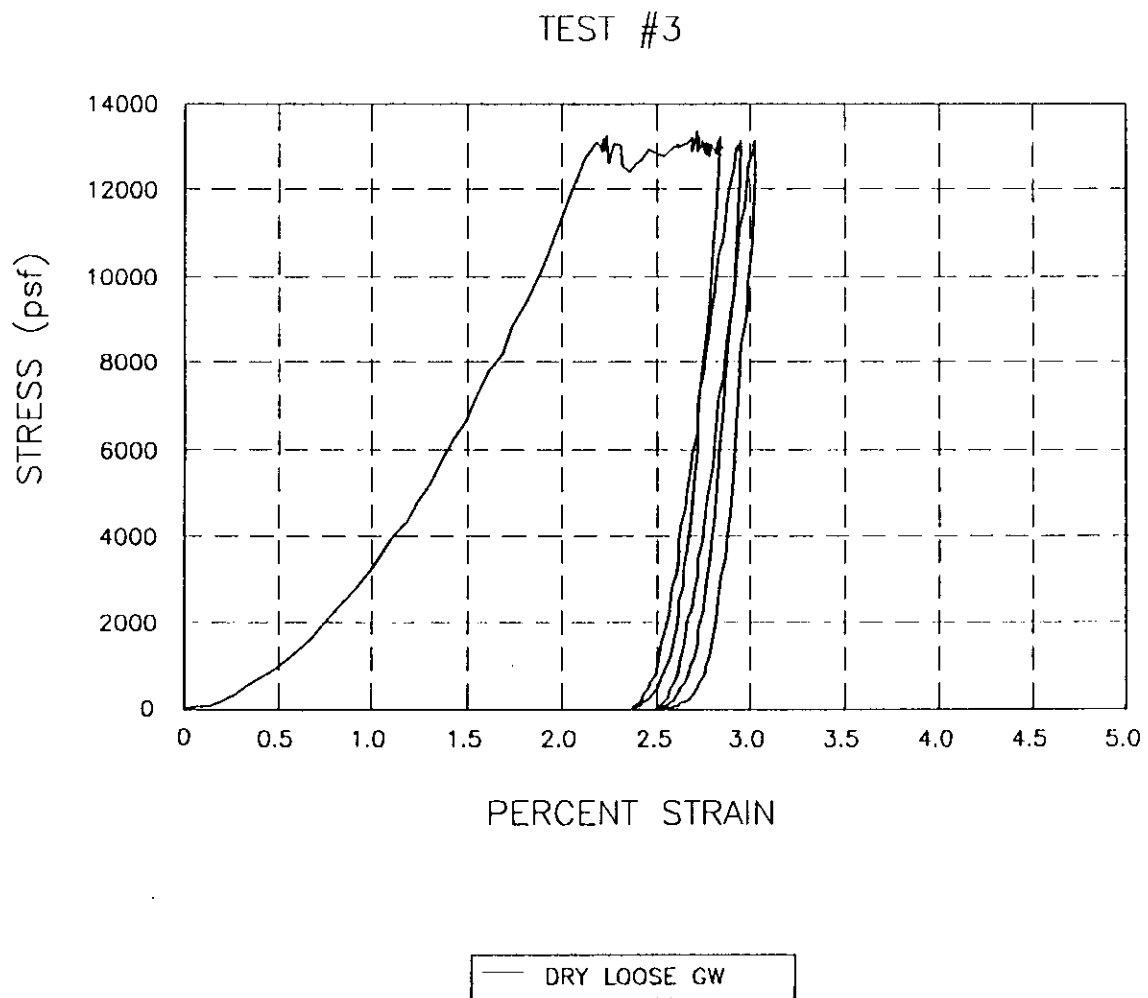
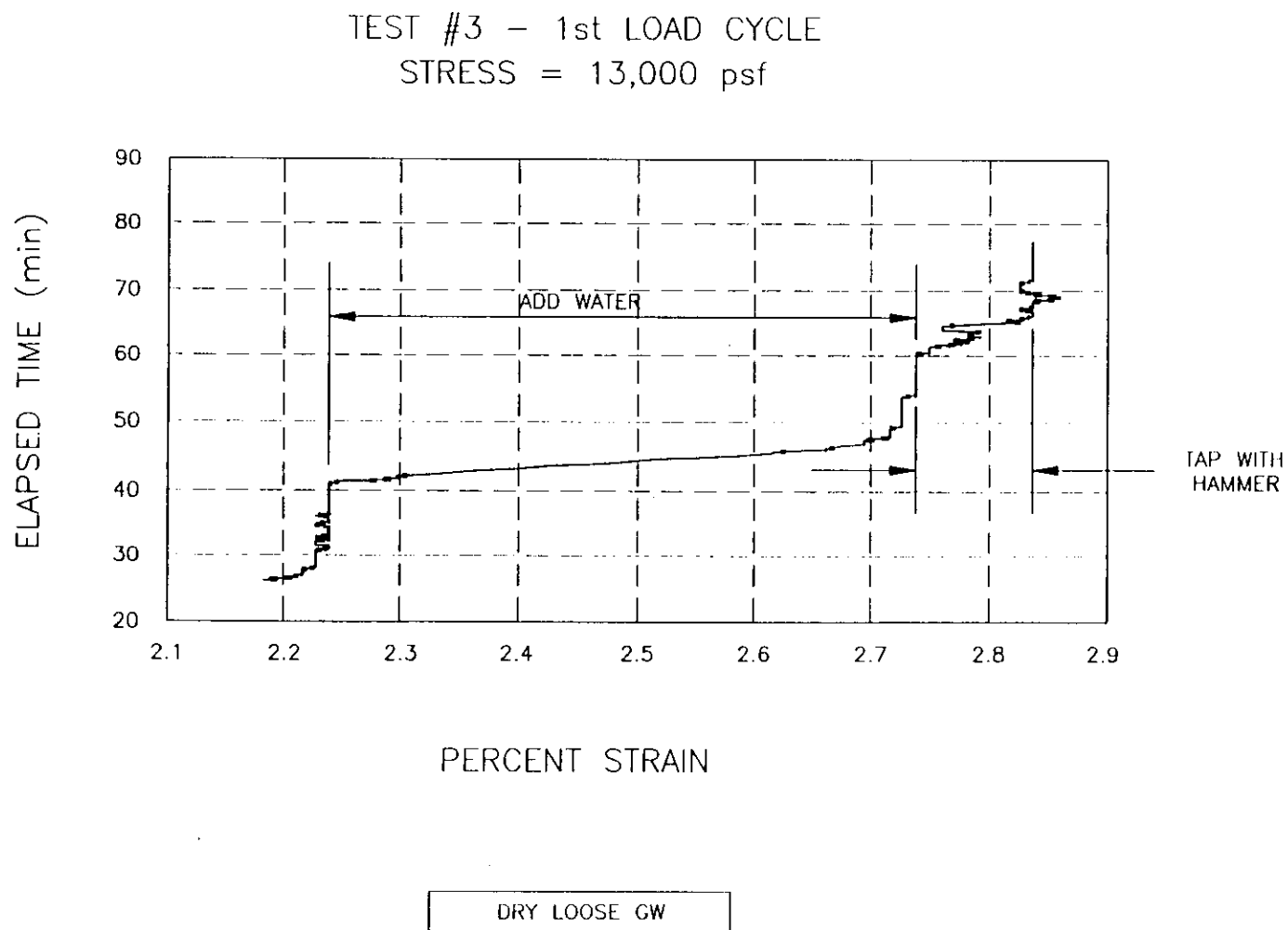


Figure E-7. Creep Curve - Loose Sample, Dry.



ERSDF Settlement Worksheet				Stress Change (psf) =		1875	
Patrick J Fox				Unit Wt (pcf) =		128	
Golder Associates - Seattle							
July 25, 1993							
Using Incremental Laboratory Moduli from Test 2 -- Dense Material							
1. Position A							
Zero Thickness --> No Settlement							
2. Position B							
Layer	Mid depth	Thickness	Init stress (psf)	D (psf)	Strain	Settlement (ft)	
1	1.5	3	192	1205000	0.00155602	0.00466805	
2	4.5	3	576	1205000	0.00155602	0.00466805	
3	7.5	3	960	1205000	0.00155602	0.00466805	
4	10.5	3	1344	1312000	0.00142912	0.004287348	
5	13.5	3	1728	1432000	0.00130936	0.003928073	
6	16.5	3	2112	1541000	0.00121674	0.003650227	
7	19.5	3	2496	1625000	0.00115385	0.003461538	
8	22.5	3	2880	1709000	0.00109713	0.003291398	
9	25.5	3	3264	1816000	0.00103249	0.003097467	
10	28.5	3	3648	1935000	0.00096899	0.002906977	
11	31.5	3	4032	2050000	0.00091463	0.002743902	
12	34	2	4352	2098000	0.00089371	0.001787417	
				Total Settlement (ft) =		0.043158496	
				Percent Settlement =		0.0012331	
2. Position C							
Layer	Mid depth	Thickness	Init stress (psf)	D (psf)	Strain	Settlement (ft)	
1	1.5	3	192	1205000	0.00155602	0.00466805	
2	4.5	3	576	1205000	0.00155602	0.00466805	
3	7.5	3	960	1205000	0.00155602	0.00466805	
4	10.5	3	1344	1312000	0.00142912	0.004287348	
5	13.5	3	1728	1432000	0.00130936	0.003928073	
6	16.5	3	2112	1541000	0.00121674	0.003650227	
7	19.5	3	2496	1625000	0.00115385	0.003461538	
8	22.5	3	2880	1709000	0.00109713	0.003291398	
9	25.5	3	3264	1816000	0.00103249	0.003097467	
10	28.5	3	3648	1935000	0.00096899	0.002906977	
11	31.5	3	4032	2050000	0.00091463	0.002743902	
12	34.5	3	4416	2098000	0.00089371	0.002681125	
				Total Settlement (ft) =		0.044052205	
				Percent Settlement =		0.001223672	

ERSDF Settlement Worksheet			Stress Change (psf) =			1875
Patrick J Fox			Unit Wt (pcf) =			116
Golder Associates - Seattle						
July 23, 1993						
Using Incremental Laboratory Moduli from Test 1 -- Loose Material						
1. Position A						
Zero Thickness --> No Settlement						
2. Position B						
Layer	Mid depth	Thickness	Init stress (psf)	D (psf)	Strain	Settlement (ft)
1	1.5	3	174	220687	0.0084962	0.025488588
2	4.5	3	522	220687	0.0084962	0.025488588
3	7.5	3	870	220687	0.0084962	0.025488588
4	10.5	3	1218	220687	0.0084962	0.025488588
5	13.5	3	1566	220687	0.0084962	0.025488588
6	16.5	3	1914	223000	0.00840807	0.025224215
7	19.5	3	2262	241000	0.00778008	0.023340249
8	22.5	3	2610	258000	0.00726744	0.021802326
9	25.5	3	2958	282000	0.00664894	0.019946809
10	28.5	3	3306	312000	0.00600962	0.018028846
11	31.5	3	3654	342000	0.00548246	0.016447368
12	34	2	3944	364000	0.0051511	0.010302198
				Total Settlement (ft) =		0.26253495
				Percent Settlement =		0.007500999
2. Position C						
Layer	Mid depth	Thickness	Init stress (psf)	D (psf)	Strain	Settlement (ft)
1	1.5	3	174	220687	0.0084962	0.025488588
2	4.5	3	522	220687	0.0084962	0.025488588
3	7.5	3	870	220687	0.0084962	0.025488588
4	10.5	3	1218	220687	0.0084962	0.025488588
5	13.5	3	1566	220687	0.0084962	0.025488588
6	16.5	3	1914	223000	0.00840807	0.025224215
7	19.5	3	2262	241000	0.00778008	0.023340249
8	22.5	3	2610	258000	0.00726744	0.021802326
9	25.5	3	2958	282000	0.00664894	0.019946809
10	28.5	3	3306	312000	0.00600962	0.018028846
11	31.5	3	3654	342000	0.00548246	0.016447368
12	34.5	3	4002	364000	0.0051511	0.015453297
				Total Settlement (ft) =		0.267686049
				Percent Settlement =		0.007435724

APPENDIX F

TRENCH FILL COMPACTION COSTS

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MEMORANDUM

TO: Larry Bennett, MW Boise

August 5, 1993

FR: Frank Shuri, GAI Redmond

RE: Megatrench Settlement, Job No. 923-A022

Enclosed is a calculation package that compares the costs for conventional compaction with dynamic compaction using a vibrating pile. These costs should be considered rough-order-of-magnitude. The costs for vibrating piles are less well defined than for conventional compaction and are quite sensitive to pile spacing and cost per linear foot of pile driving. To accommodate this uncertainty, a range of costs has been included. The unit costs for conventional (vibrating roller) compaction is \$120,000 per acre. Unit costs for vibrating pile compaction are \$85,000 to \$275,000 per acre. For the 33-foot-deep Megatrench (600 acres to be compacted), these values translate into \$72,000,000 for conventional compaction and \$51,000,000 to \$165,000,000 for vibrating pile compaction. It appears that dynamic compaction can be comparable to conventional compaction, but if less favorable conditions are present, the cost could be substantially higher. Given the large cost impact, field tests are justified to determine pile spacing and driving rates.

Objective: Compare Costs for conventional compaction with vibrating drum roller and compaction with vibrating pile

① Conventional Compaction.

Assume: Dozer will spread waste soil
Large vibrating drum roller will compact
Lift is 1-foot thick
2 passes for compaction
No added water for compaction
Trench is 33 ft deep
Allow extra 50% for safety, shuelding, etc.

Use Means 1993 Site Work + Landscape Cost Data

Means 022 262 0010: Spread dumped material,
no compaction: \$1.33/yd³

Means 022 226 5060: Riding Vibratory rollers,
12" lift, 2 passes: \$0.15/yd³

Total: \$1.48/yd³ ✓

x 150% (safety) \$2.22/yd³ ✓

$$\frac{\$2.22}{\text{yd}^3} \times \frac{1 \text{ yd}^3}{27 \text{ ft}^3} \times \frac{1 \text{ ft}^3}{1 \text{ ft}^2} = \$0.082/\text{square foot}$$

$$\$0.082/\text{ft}^2 \times 33 \text{ ft} \times 43560 \text{ ft}^2/\text{acre} = \$118,193/\text{acre} ✓$$

Say \$120,000/acre ✓

② Vibrating Pile Compaction

Assume: Trench is 33 ft. deep
15 ft spacing between piles
Allow extra 10% for rad. monitoring, safety

Determine cost per linear foot of pile:

① Look at sheet piles:

Means 021 614 1000, 38 psf sheet pile,
drive, extract, and salvage: \$500/ton.

Assume pile = 10" x 10" H-pile, 57 lb/ft
(Means 023 608 0500)

$$\$500/\text{ton} \times 57 \text{ lb}/\text{ft} \times 1 \text{ ton}/2000 \text{ lb} = \$14.25/\text{ft} \checkmark$$

② Look at Vibro flotation:

Means 022 504: Sand cylinder: \$3.83 to \$8.85/ft

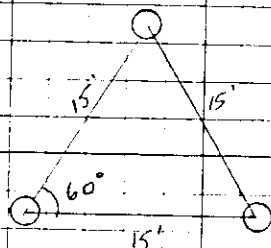
Stone cylinder: \$5.75 to \$11.50/ft \checkmark

③ Look at H-piles:

Means 023 608 0500, 10" x 10" H pile,
57 lb/ft: \$21/ft

On basis of three costs, large quantity, assume \$10/HF \checkmark

Determine number of treatment sites per acre.



1/2 pile treats each triangular area

$$A = \frac{1}{2} b h$$

$$= \frac{1}{2} 15 \cdot 15 \sin 60^\circ$$

$$= 97.43 \text{ ft}^2 \checkmark$$

$$\therefore 1 \text{ treatment affects } 2 \times 97.43 = 194.86 \text{ ft}^2 \checkmark$$

SUBJECT Compaction Method Costs

Job No. 923-A022

Made by FSS

Date 8-5-93

Ref. ERSDF - Mega trench

Checked RDL

Sheet 3 of 8

Reviewed

$$1 \text{ treatment} / 195 \text{ ft}^2 \times 43560 \text{ ft}^2 / \text{acre} = 223 \text{ treatments/acre} \checkmark$$

$$223 \text{ treatments/acre} \times 33 \text{ ft/treatment} \times \$10/\text{ft} = \$73,590/\text{acre} \checkmark$$

$$\$73,590/\text{acre} \times 110\% (\text{safety}) = \$80,949/\text{acre} \checkmark$$

$$\text{Say } \$85,000/\text{acre} \checkmark$$

Note: This estimate is very sensitive to pile spacing.

If the spacing must be decreased to 10 ft,
the Area per treatment is

$$2 \times \frac{1}{2} \times 10^2 \sin 60^\circ = 87 \text{ ft}^2 \checkmark$$

$$\text{and the cost per acre becomes } \$80,949 \times \frac{195}{87} \\ = \$182,270 \checkmark$$

If in addition, the cost of treatment is \$15/ft
rather than \$10/ft, the cost per acre
becomes

$$\$182,270 \times \frac{15}{10} \\ = \$273,405 \checkmark$$

$$\therefore \text{range} = \$85,000 \text{ to } \$275,000/\text{acre}$$

③ Total Cost: assume 600 acres (see Fig 5.3-2, attached, and decrease
to allow for perimeter zone, central berm)
for Megatrench A

$$\text{Conventional compacting: } 600 \text{ acres} \times \$120,000 = \$72,000,000 \checkmark$$

$$\text{Vibrating Pile: } 600 \text{ acres} \times \$85,000 = \$51,000,000 \checkmark$$

$$\text{to } 600 \text{ acres} \times \$275,000 = \$165,000,000 \checkmark$$

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Material	Source	Unit Cost, per yd ³		Volume, yd ³		Volume, yd ³	
		Imported	On-Site Processing	Required	Available	Required	Available
Admixing Soil (Liner)	Sandy Sequence	N/A	\$0.00	2.11	15.00	2.11	15.00
Silt (Hanford Barrier)	Sandy Sequence	\$8.00	\$12.00	2.11	15.00	2.11	15.00
Filter Sand (Hanford Barrier)	Sandy Sequence	\$10.00	\$6.00	2.11	15.00	2.11	15.00
Pea Gravel (Hanford Barrier)	Upper Gravel	\$6.50	\$16.00	2.11	15.00	2.11	15.00
Filter & Drain Rock (Hanford Barrier)	Upper Gravel	\$6.50	\$6.00	2.11	15.00	2.11	15.00
Capillary Break (Hanford Barrier)	Upper Gravel	\$26.00	\$16.00	2.11	15.00	2.11	15.00

ENGINEERING DIV. _____ BRANCH _____ SECTION _____

PROJECT _____

SUBJECT _____

BY _____ DATE 4-13 CHECKED _____ PART _____ PAGE 1 OF 1

ALT 1

Total of 23.1 mcy excavated

0.30 mcy used as admixing soil

1.53 mcy used as Filter Sand

1.53 mcy used as Filter Sand

0.30 mcy used as Capillary Break

1.70 mcy used as random cover

2.24 mcy used as operational layer

2.35 mcy used as ~~filter sand~~ embankment $\Sigma 12.0$ mcy mat'l left over = 12.0 mcyALT 2 Total of 25.5 mcy excavated

1.78 mcy used as admixing soil

0.30 mcy used as Filter Sand

1.22 mcy used as Filter + Drain Rock

0.31 mcy used as Capillary Break

1.57 mcy used as random cover

1.61 mcy used as operational layer

1.07 mcy used as embankment

 $\Sigma 8.06$ mcy mat'l left over = 17.44 mcy

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ENGINEERING DIV. BRANCH

SECTION

PROJECT BRIDGESUBJECT BRIDGEBY DATE CHECKED PART PAGE OF

Investigation was made of the bridge from the bridge at the west end and a depth of 12 feet was reached. The MWD of the soil was 1-3-70, 1-30-70, 1-30-70, 1-30-70, 1-30-70, 1-30-70, 1-30-70 and 1-30-70. The laboratory tests were made and the results are as follows.

Material

1-30-70

Silt

Filter sand

Pebbles

Filter sand

Capillary break

Material

(1) 1-30-70

(2) 1-30-70

(3) 1-30-70

(4) 1-30-70

(5) 1-30-70

(6) 1-30-70

Gravels for samples 1 and 2 were not included in the 1-30-70. So the gravel for 3 was used to correlate specimens for (2), and (4). The gravel was used from Trench and the 1-30-70 was used from the report. The 1-30-70 is located to the north of the EXDF 1-30-70.

Gravel	Sizes	Sample 1	Sample 2	Av.
RA gravel	10-1"	10%	39%	9%
Fill + D.R.K.	#10-1"	55%	47%	51%
Cap. Brk.	2" +	20%	20%	20%

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SUBJECT _____

BY	DATE	CHECKED	PART	PAGE	OF
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1. The first part of the document is a list of names and dates, which appears to be a record of some kind. The names are written in a cursive script, and the dates are in a more formal, printed style. The list is organized into two columns, with names on the left and dates on the right.

	1944	1945	1946	1947
male	2	15.0	10	1.17
female	15	5.10	10	2.23
total	17	20.10	20	3.40
grand total	32	30.20	30	5.57

$$T_{\text{max}} = 23.1^\circ\text{C}$$

Trend At-2 = -0.000256

Journal of Management Studies, 1987, Vol. 20, No. 6, pp. 631-641.

	2000	2001	2002
mall	14	14	14
Rd 1000	0.39	0.21	0.23
RR 51	1.53	1.17	1.30
Ln 20	0.60	20	0.21

For Random Mail, speed of mail, and emergency mail, it was assumed that an excess mail would be suitable.

ENGINEERING DIV. BRANCH SECTION

PROJECT _____

SUBJECT _____

BY _____ DATE _____ CHECKED _____ PART _____ PAGE _____ OF _____

1000 - 10000
 1000 - 10000
 1000 - 10000
 1000 - 10000
 1000 - 10000

[illegible]

- Subgrade - natural material on which the road is constructed
- Sub base and Base - over the subgrade
- Wearing Layer (thin layer)
- Embankment (Ramp side)
- Shoulder - Engineered surface material
- Asphalt

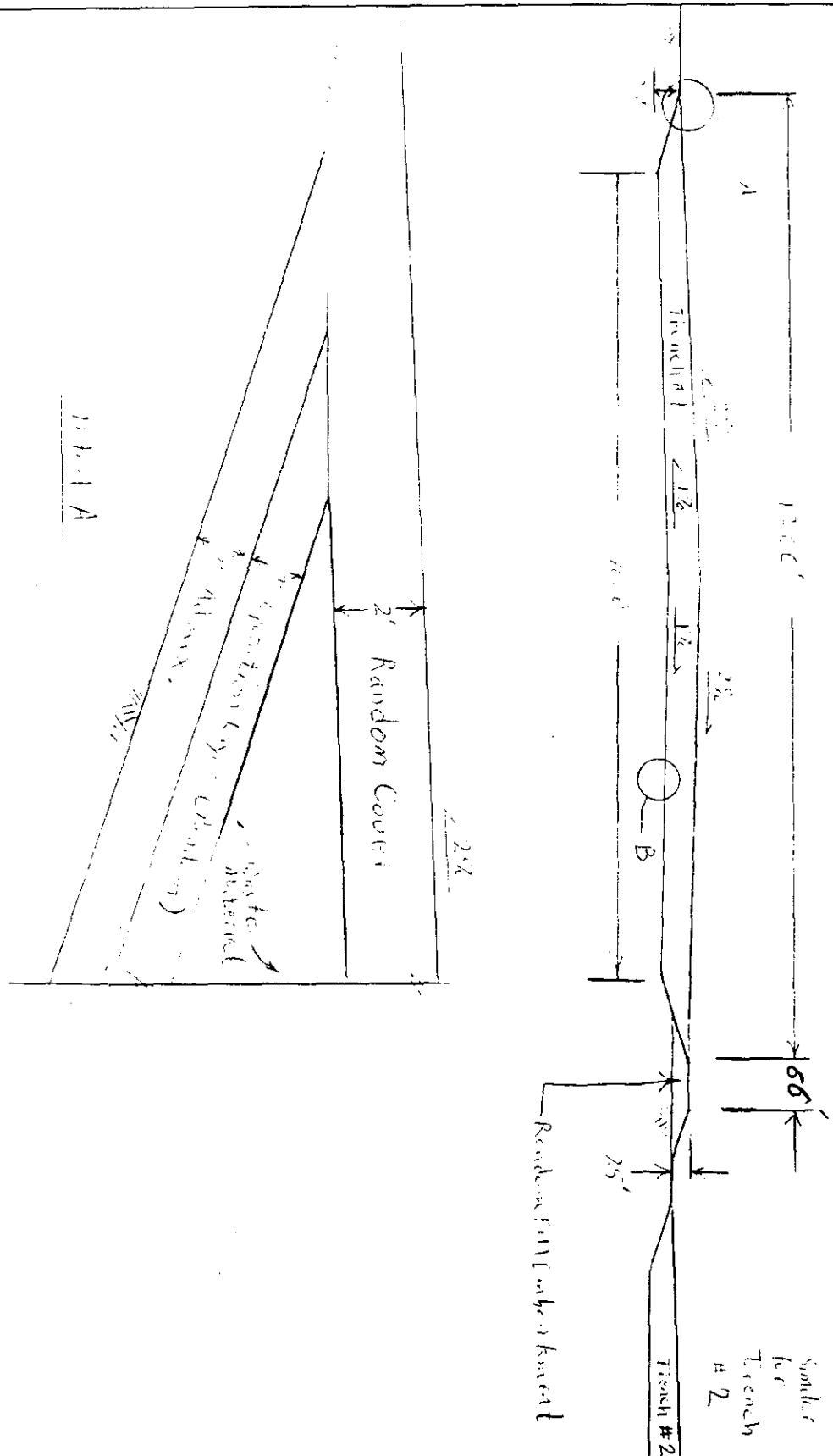
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ENGINEERING WORKSHEET

Prepared by
Date
Subject

Project

STANDARD 1111
Cable Trenches (3' Deep)



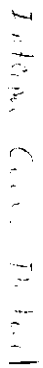
Sheet A

1200'
25'
66'
25'
Trench #2
Random fill under concrete

1000

[illegible]

MILIKMAN, L.V. #2
(see Touch 7-14-69)



ENGINEERING DIV.

BRANCH

SECTION

PROJECT

SUBJECT

BY

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OF

MT.

X-section area of waste material = 2,000 sq

ft² = 20.0 MC = 19.5 MC

X-section area of waste material = 20.0

X-section area of waste material = 19.5 MC

MT. 2

X-section area of waste material = 79.5 MC

X-section area of waste material = 79.5 MC

X-section area of waste material = 79.5 MC